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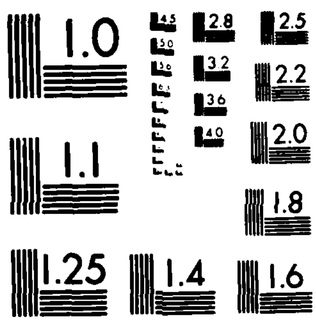

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TECHNICAL REPORT RE-83-7

ANALYTICAL RESEARCH BY COMPUTER SIMULATION OF DEVELOPMENTAL POLARIMETRIC/FREQUENCY AGILE PULSED RADARS

R. F. Russell and F. W. Sedenquist
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December 1982

U.S. ARMY MISSILE COMMAND
Redstone Arsenal, Alabama 35809

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A new generation of radar systems that exploit the polarization characteristics of various targets and clutter are under development. This report examines the methods of simulating these new techniques and presents typical results.

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CONTENTS

I. INTRODUCTION

Radio frequency (rf) systems that utilize the polarization characteristics of the target and environment to detect, track, identify, etc., are referred to as rf polarimetric systems. These systems usually combine the polarization characteristics with frequency agility for increased range resolution. Examples of such radar systems are the Multi-environment Active Radio Frequency Seeker (MARFS), the Advance Indirect Fire System (AIFS), the Helicopter All Weather Fire Control and Acquisition Radar (HAWFCAR), and the Polarimetric Technology Seeker (PTS) as well as various other R&D radars under development by numerous independent contractors in private industry.

The demand for a more complete understanding of the techniques and processess employed in various programs has precipitated the development of the polarimetric radar simulation. This document covers the mathematical analysis required as background, the computer simulation model, and typical results. Recommendations for future expansions of this model are also addressed.

II. MATH MODEL DEVELOPMENT

A. Polarization Definition

The concept of polarization and the associated conventions are vital to the understanding of the use of the polarization scattering matrix. The definitions of polarization have been traditionally either the physics or the engineering convention. Either convention will provide the same general answer but with different notation. Therefore, the convention to be used throughout this analysis is as stated in the IEEE STD 211-1977 "IEEE Standard Definitions of Terms for Radio Wave Propagation".

Linearly Polarized Wave - An electromagnetic wave whose electric and magnetic field vectors always lie along fixed lines at a given point. (Page 9.)

Left-handed (counterclockwise) polarized wave - An elliptically polarized electromagnetic wave in which the rotation of the electric field vector with time is counterclockwise for a stationary observer looking in the direction of the wave normal.

NOTE: For an observer looking from a receiver toward the apparent source of the wave, the direction of rotation is reversed. (Page 9.)

The definition of right-handed is found on page 12 and is the same as above with the word clockwise used instead of counterclockwise.

B. Plane Waves

For a plane time harmonic electromagnetic wave traveling in free space the electric field intensity vector $\overline{E}(t)$, and the magnetic field intensity vector $\overline{H}(t)$ are always orthogonal to one another and have directions specified by the right hand rule as defined in the complex Poynting vector ($\overline{S}$).

$$\overline{S} = \overline{E} \times \overline{H}$$

Since $\overline{E}$ and $\overline{H}$ are always coupled together, it is customary to specify the $\overline{E}(t)$ vector only in describing the plane wave. The plane wave can be specified by its amplitude, frequency, direction of propagation, and polarization.

The vector wave equations for waves in free space* can be written as

$$\nabla^2\overline{E} + k^2\overline{E} = 0$$

$$\nabla^2\overline{H} + k^2\overline{H} = 0$$

where k is the complex wave number. The rectangular components of $\overline{E}$ and $\overline{H}$ satisfy the complex scalor wave equation (commonly called the Helmholtz equation):

$$\nabla^2\Psi + k^2\Psi = 0$$

The solution to the Helmholtz equation for one component, say x, thus reduces to

$$\frac{d^2E_x}{dz^2} + k^2E_x = 0$$

which is the one dimensional Helmoholtz equation. The equation has solutions that are linear combinations of e^{jkz} and e^{-jkz}. We can choose to work with either of these solutions, though, in engineering we generally use the form e^{-jkz}: in particular, consider the solution

$$E_x = E_o e^{-jkz}$$

This satisfies the $\nabla\cdot\overline{E}=0$, and is therefore a possible electromagnetic field.

To interpret this solution, let E_o be the rms value; then the instantaneous field is found to be

$$\xi x = \sqrt{2}\, E_o \cos (wt-kz)$$
$$\xi y = \sqrt{2}\, E_o \cos (wt-kz)$$

For conventions' sake, the x direction will be the horizontal polarization and the y direction will be the vertical polarization. In general the two waves need not have the same phase. Again, for convention, it will be assummed that all phase shifts between the two waves are referenced to the horizontal wave. Therefore, the final form of the wave equation can be written as

$$\overline{E}_x(r,t) = E_H e^{j(wt-kz)}\overline{a}_x$$

$$\overline{E}_y(r,t) = E_V e^{j(wt-kz\pm\beta_o)}\overline{a}_y$$

*"Time-Harmonic Electromagnetic Fields" Roger F. Harrington, McGraw-Hill Book Co., 1961.

where

E_H is electric field strength polarized in the horizontal direction.
E_V is electric field strength polarized in the vertical direction.
ω is the radian frequency of the transmitted wave.
k is the complex wave number.*
t is time
z is distance (when z = range to target z = R)
β_o is the phase difference between horizontal and vertical electric field waves at the transmitting antenna. ($-\pi \leq \beta_o \leq \pi$)
$\underline{a}_y$ is a unit vector in the Y direction (vertical)
$\underline{a}_x$ is a unit vector in the X direction (horizontal)
$\underline{a}_z$ is a unit vector in the Z direction (range)

C. Special Cases of Polarization

1. Linear (see Figure 1)

$\beta_o = 0$

$\overline{V}_T = E_v e^{j(wt-kz)} \overline{a}_y$ or $E_v \cos (wt-kz) \overline{a}_y$

$\overline{H}_T = E_H e^{j(wt-kz)} \overline{a}_x$ or $E_H \cos (wt-k_z) \overline{a}_x$

$\rho = \arctan V_T/H_T = \arctan E_V/E_H$

*($k = k' - jk''$) where k' is the intrinsic phase constant and k" is the intrinsic attenuation constant. When no attenuation is assumed $k = k' = 2\pi/\lambda$.

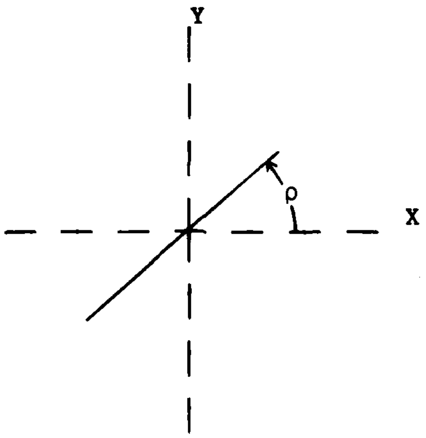


Figure 1 Linear polarization

ρ equal zero is referred to as horizontal polarization.
ρ equal ninety degrees is referred to as vertical polarization.
ρ equal forty five degrees is 45 degree linear polarization.

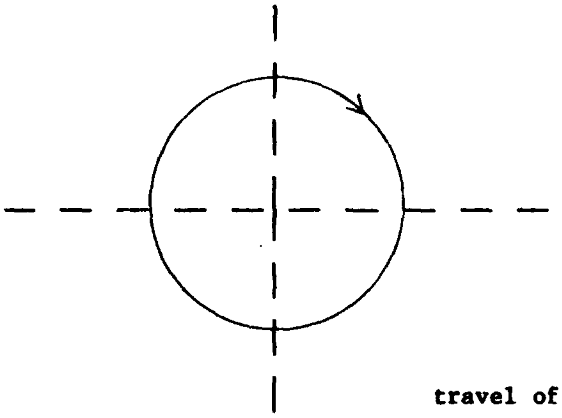
2. Circular (see Figures 2 and 3)

$\beta_o = \pm 90°$

$E_v = E_H = E$

Left hand circular $\beta_o = 90°$ or $\pi/2$ radians.

The loci is a circle of radius E. The electric field vector is constant in magnitude. When looking in the direction of travel the electric field vector rotates counterclockwise: when looking against the direction of travel the vector rotates clockwise.



travel of $\bar{E}$ is out of the page

Figure 2. Left hand circular polarization.

Right hand circular

$\beta_o = -90°$ or $-\pi/2$ radians

$E_v = E_H = E$

The Loci is a circle of radius E. However, the electric field is rotating clockwise with time when viewed in the direction of travel, and counterclockwise when the observation is made looking against the direction of travel.

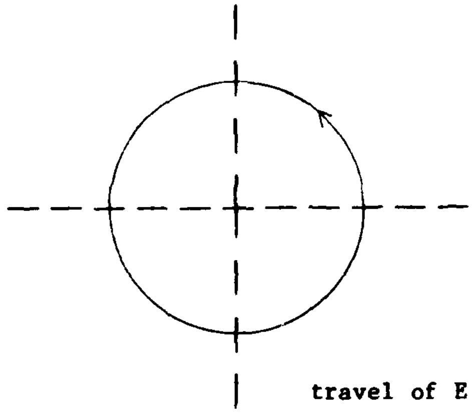


Figure 3. Right hand circular polarization

3. Elliptical (see Figure 4)

   $\sin \beta_o > 0$ left hand elliptical
   $\sin \beta_o < 0$ right hand elliptical

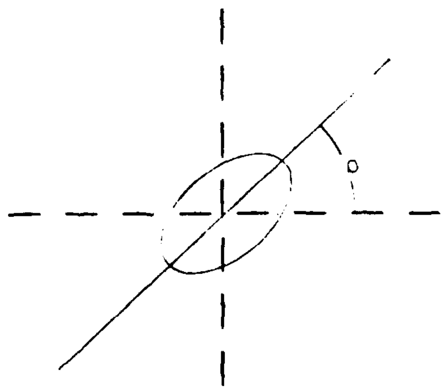


Figure 4. Elliptical polarization

The angle ρ is the angle to the major axis e and is dependent upon the ratio of E_V, E_H, and β_o.

D. Polarization Notation

As previously presented, a pure left hand circular polarized wave electric field may be shown as

$$\overline{E}_{T_L} = E[\cos(wt-kz)\overline{a}_x - \sin(wt-kz)\overline{a}_y]$$

and a pure right hand circular polarization as

$$\overline{E}_{T_R} = E[\cos(wt-kz)\overline{a}_x + \sin(wt-kz)\overline{a}_y]$$

For simplicity the time dependency given originally as e^{jwt} may be suppressed or removed and a circular wave can be represented as

$$\overline{E}_{T_L} = E[\cos(-kz)\overline{a}_x - \sin(-kz)\overline{a}_y]$$

$$\overline{E}_{T_R} = E[\cos(-kz)\overline{a}_x + \sin(-kz)\overline{a}_y]$$

Assuming the electric field at the transmitter (z=0) is 90° (plus or minus) out of phase in the H and V direction, or

$$\overline{E}_{T_L} = E\overline{a}_x + Ee^{j\pi/2}\overline{a}_y$$

$E_{T_L} = E + jE$ for left hand circular (see Figure 5)

Therefore

$E_{T_R} = E - jE$ for right hand circular

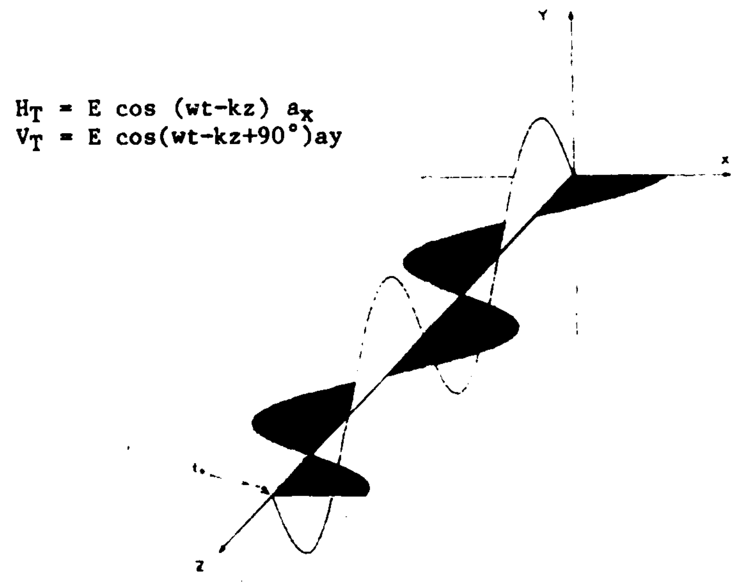


Figure 5. Left hand circular wave traveling in Z direction.

E. Scattering Matrix

Scattering of a wave by objects in the field of view is modeled by the polarization scattering matrix as

$$[\overline{E}^R] = [S][\overline{E}^T] \cdot \frac{1}{\sqrt{4\pi R^2}}$$

where $\overline{E}^R$ is received electric field vector

$\overline{E}^T$ is transmitted electric field vector

$$[S] = \begin{bmatrix} S_{HH} & S_{HV} \\ S_{VH} & S_{VV} \end{bmatrix}$$

It can be shown that the scattering matrix is related to radar cross section in the following manner:

$$[S] = \begin{bmatrix} \sqrt{\sigma_{HH}}e^{j\phi_{HH}} & \sqrt{\sigma_{HV}}e^{j\phi_{HV}} \\ \sqrt{\sigma_{VH}}e^{j\phi_{VH}} & \sqrt{\sigma_{VV}}e^{j\phi_{VV}} \end{bmatrix}$$

For convenience, the $\frac{1}{\sqrt{4\pi R^2}}$ term is usually dropped and the received electric field components are shown to be related by

$$[\overline{E}^R] = [S]\ [\overline{E}^T]$$

Therefore, for a monostatic radar the voltage at the antenna terminals is related as

$$[\overline{E}^R] = \begin{bmatrix} E_H \\ E_V \end{bmatrix} = [S] \begin{bmatrix} E_H^T \\ E_V^T \end{bmatrix} \cdot \frac{1}{K}$$

where K is some factor that represents the appropriate radar range scaling, which for most calculations is not considered unless the absolute received voltage is required.

For a left hand circular transmitted wave this becomes

$$[E^R] = \begin{bmatrix} E_H \\ E_V \end{bmatrix} = [S] \begin{bmatrix} Ee^{j(wt-2kR)} \\ Ee^{j(wt-2kR+\pi/2)} \end{bmatrix}$$

where R is now the one way range to the target from the radar.

In short hand notation this can be written as

$$[E^R] = [S] \begin{bmatrix} E^T \\ jE^T \end{bmatrix}$$

F. Scattering Matrix for Simple Objects

The polarization scattering matrix in its most generic form is written as

$$[S] = \begin{bmatrix} S_{11}e^{j\phi_{11}} & S_{21}e^{j\phi_{21}} \\ S_{12}e^{j\phi_{12}} & S_{22}e^{j\phi_{22}} \end{bmatrix}$$

where the subscripts refer to orthogonal components, the first subscript being receive, and the second transmit.

In the linearly polarized form this becomes

$$[S] = \begin{bmatrix} S_{HH}e^{j\phi_{HH}} & S_{HV}e^{j\phi_{HV}} \\ S_{VH}e^{j\phi_{VH}} & S_{VV}e^{j\phi_{VV}} \end{bmatrix}$$

In the circular polarized form this becomes

$$[S] = \begin{bmatrix} S_{RR}e^{j\phi_{RR}} & S_{RL}e^{j\phi_{RL}} \\ S_{LR}e^{j\phi_{LR}} & S_{LL}e^{j\phi_{LL}} \end{bmatrix}$$

where R refers to right hand circular, and L to left hand circular.

In this analysis where a circular wave (right or left) is broken into its horizontal and vertical components the linearly polarized scattering matrix must be used. However, the same results could be obtained by using the circular scattering matrix and not breaking down the electric field into orthogonal components of E_H and E_V.

Consider an odd bounce reflector (a flat plate) that totally reflects the transmitted wave. The linear scattering matrix elements can be written as

$$S_{11} = S_{HH},\ S_{12} = S_{HV},\ S_{21} = S_{VH},\ S_{22} = S_{VV}$$

The return from an impinging horizontal electrical field will have the same magnitude but the phase will shift 180°. The same is true for an impinging vertical electric field. A horizonal electic field striking a flat plate and being received in the vertical direction is zero. The same is true for transmit vertical/receive horizonal.

The scattering matrix for a flat plate is therefore

$$[S]_{FP} = \begin{bmatrix} -1 & 0 \\ 0 & -1 \end{bmatrix}$$

It should be noted that the 180° phase shift is due to the electromagnetic boundary condition of zero tangential field at the surface of a perfect conductor. This matrix could have been written as

$$[S]_{FP} = \begin{bmatrix} e^{-j\pi} & 0 \\ 0 & e^{-j\pi} \end{bmatrix}$$

noting that e = -1.

The same odd bounce reflector in a circlar scattering matrix would have the following elements

$$S_{11} = S_{RR}; \quad S_{12} = S_{RL}; \quad S_{21} = S_{LR}; \quad S_{22} = S_{LL}$$

The rotation of the return from a circularly polarized wave will be the reverse of the rotation of the transmitted wave; that is, right hand transmitted becomes left hand received. Because there is only a cross polarization component, the circular scattering matrix for a flat plate (odd) is

$$[S]_{FP} = \begin{bmatrix} 0 & 1 \\ 1 & 0 \end{bmatrix}$$

The equivalence of linear polarization and circular polarization can best be seen from examples of both worked in parallel. Assume a left hand circular transmit into a flat plate.

The circular (left hand) transmit is written in a linear system as

$$E_L^T = E\overline{a}_x + jE\overline{a}_y$$

A circular transmit system is written in circular notation as

$$E^T_{\overline{a}r} = E_{\overline{R}}^T + E_{\overline{L}}^T$$

where $\overline{R}$ is a unit vector rotating in the right hand direction

$\overline{L}$ is a unit vector rotating in the left hand direction

LINEAR (FLAT PLATE)	CIRCULAR (FLAT PLATE)
$\begin{bmatrix} E_H^R \\ E_V^R \end{bmatrix} = \begin{bmatrix} -1 & 0 \\ 0 & -1 \end{bmatrix} \begin{bmatrix} E_H^T \\ jE_V^T \end{bmatrix}$	$\begin{bmatrix} E_R^R \\ E_L^R \end{bmatrix} = \begin{bmatrix} 0 & 1 \\ 1 & 0 \end{bmatrix} \begin{bmatrix} 0 \\ E_L^T \end{bmatrix}$
$E_H^R = -E_H^T$	$E_R^R = E_L^T$
$E_V^R = -jE_V^T$	$E_L^R = 0$
Noting that the direction of travel has reversed the received wave is of the form	In the circular form the received wave is of the form
$E^R = -E_H^T - jE_V^T$	$E = E_L^T\bar{R} + 0$
which is a right hand circular wave traveling in the -z direction.	which is a right hand circular wave.

Figure 6. Scattering characteristics.

The analytical relationships developed for the simulation are based upon the linear scattering characteristics of a few simple shapes, classified to some degree by the number of reflecting surfaces encountered.

1. Odd bounce scattering matrix (flat plate, trihedral corner reflector) for linear polarization (see Figure 6)

$$\begin{bmatrix} e^{-j\pi} & 0 \\ 0 & e^{-j\pi} \end{bmatrix} \quad \text{or} \quad \begin{bmatrix} -1 & 0 \\ 0 & -1 \end{bmatrix}$$

2. Even bounce scattering matrix (diplane) for linear polarization

$$\begin{bmatrix} \cos 2\theta & \sin 2\theta \\ \sin 2\theta & -\cos 2\theta \end{bmatrix}$$

where θ is the angle of rotation of the diplane relative to the horizontal. (See Figure 7).

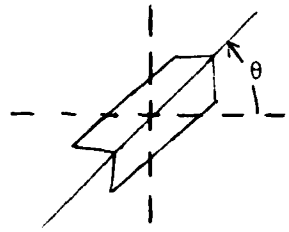


Figure 7. Diplane rotation angle.

3. Dipole matrix for linear polarization (Figure 8).

$$\begin{bmatrix} -\cos 2\theta & -\cos\theta\sin\theta \\ -\cos\theta\sin\theta & -\sin 2\theta \end{bmatrix}$$

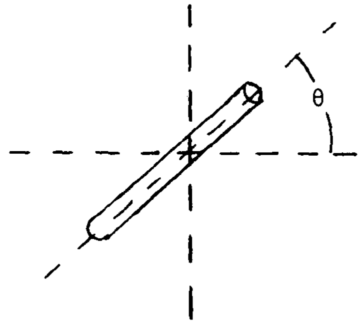


Figure 8. Dipole rotation angle.

It is assumed that superposition holds such that a complex target may be modeled by an ensemble of these even and odd bounce targets or scatterers with the inclusion of their respective ranges.

G. Radar Range Scaling

The basic radar equation to determine the power received at the radar is

$$P_r = \frac{P_t G^2 \lambda^2 \sigma}{(4\pi)^3 R^4 L_s}$$

where P_r is power received in watts
P_t is peak power transmitted in watts
G is antenna gain (unitless)
λ is wavelength in meters
σ is radar cross-section in meters squared
R is range to target in meters
L_s is system loss (unitless)

Because this analysis is performed in the voltage domain the standard radar equation must be modified to be expressed in terms of voltage.

$$P_r = (V_{peak}/\sqrt{2})^2/Z$$

where Vpeak is peak voltage received
Z is impedance (assumed 50 ohms)

Therefore, the peak voltage (Vpeak) is

$$V_{peak} = \sqrt{2*Z*P_r}$$

By removing the radar cross-section from P_r, P_r becomes a constant radar scalar which when used with the field voltage obtained from the scattering matrix defines the peak received voltage.

$$V_{peak} = \sqrt{\frac{2ZP_tG^2\lambda^2}{(4\pi)^3R^4L_s}} \cdot \sqrt{\sigma}$$

H. <u>Noise Generation</u>

If the radar were operated in a perfectly noise free environment so that no external noise sources accompanied the desired signal, there would still exist an unavoidable component of noise generated by the thermal motion of the conduction electrons in the receiver input stages. This is called thermal noise and is directly proportional to the temperature of the ohmic portions of the circuit, and the receiver bandwidth. The available thermal-noise power generated by a receiver of bandwidth B_n (in Hz) at temperature T (degrees Kelvin) is equal to:

$$\text{average available power} = KTB_n$$

where K is Boltzmann's constant (1.38×10^{-23} joule/deg)

No matter whether the noise is generated by a thermal mechanism or by some other mechanism, the total noise at the output of the receiver may be considered to be equal to the thermal-noise power obtained from an ideal receiver multiplied by a factor called noise figure (NF). The noise figure (NF) of a receiver is defined by the equation:

$$NF = \frac{\text{noise out of practical receiver}}{\text{noise out of ideal receiver at Std Temp } (T_o)}$$

The standard temperature is taken to be 290° K.

Therefore,

$$\text{average available power} = KT_oBNF$$

Assuming this to be the available average power at the input stages of a radar, the ohmic load is assumed to be matched as in the simple circuit diagram in Figure 9.

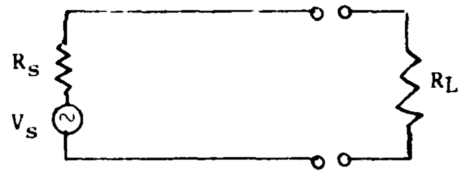


Figure 9. Equivalent noise circuit.

NOTE: Load resistance (R_L) is matched to source resistance (Rs).

Therefore, the RMS voltage available at the source can be calculated as

$$V_s = 2V_L$$

$$V_L = \sqrt{KT_oBNFR_L} \quad \text{and} \quad V_s = 2\sqrt{KT_oBNFR_L}$$

The noise entering the IF amplifier is assumed to be Gaussian, with a probability-density function given by

$$p(v)dv = \frac{1}{\sqrt{2\pi\Psi}} \exp\left(\frac{-v^2}{2\Psi_o}\right) dv$$

where p(v) dv is the probability of finding the noise voltage between the value of v and v + dv, Ψ_o is the variance, or mean-square value of the noise voltage. The mean value of v is taken to be zero.

Therefore, the mean-square value is taken to be V_L^2 or KT_oBNFR_L and the standard deviation by definition is

$$SD = \sqrt{KT_oBN_FR_L}$$

I. Antenna Isolaton

When two antennas (or elements) are widely separated the energy coupled between them is small, and the influence of the receiving antenna on the current excitation and pattern of the transmitting antenna is negligible. As the antennas (or elements) are brought closer together the coupling between them increases.

Isolation of a polarimetric antenna is represented as two antennas that cross couple energy during transmit and receive. Considering only the transmit cycle the coupling can be represented as in Figure 10.

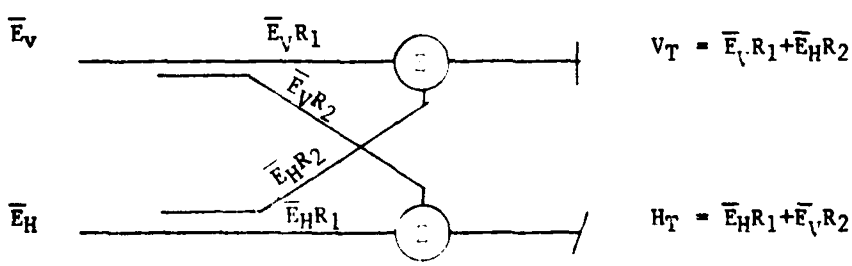


Figure 10. Transmit isolation.

In Figure 10 $\overline{E}_V$ and $\overline{E}_H$ are input to the antenna, and $\overline{V}_T$ and $\overline{H}_T$ are antenna outputs.

$$R_2 = 10^{-ISOL/20} \qquad R_1\sqrt{1-10^{ISOL/10}}$$

ISOL is the antenna isoluation in dB one way, always positive.

Assuming reciprocity, the isolation upon receive is

$$\overline{E}_{VR} = \overline{V}_R R_1 + \overline{H}_R R_2$$

$$\overline{E}_{HR} = \overline{H}_R R_1 + \overline{V}_R R_2$$

where $\overline{E}_{VR}$ and $\overline{E}_{HR}$ are the input signals to the receiver and $\overline{H}_R$ and $\overline{V}_R$ are the inputs at the antenna plane.

Phase stability is assumed across the antenna plane.

J. Frequency Agility and Intra-Range Resolution

Range resolution is usually defined as the distance at which two targets can be resolved in range. In the conventional radar this is defined by the pulse width of the transmitted wave as $\Delta R = (C\tau/2)$

where ΔR is range resolution (m)
C is velocity of light (m/sec)
τ is radar pulsewidth (sec)

Considering the radar to have a match receiver τ, equal to one over receiver bandwidth, ΔR becomes

$$\Delta R = \frac{C}{2B}$$

where B is bandwidth in Hertz.

Either of the two equations can be used to calculate the range resolution of a radar. However, the latter equation is the more general form and can be ulitized in calculating range resolution in conventional radar, pulse compression radar, and frequency agile radar, as well as in hybrids of these such as the pulse compression frequency agile radar.

Ruttenberg showed in 1967 a method that increased range resolution with a *non-coherent* source. This involved a frequency agile scheme that summed the pulses after they were received (coherent on receive) and delayed by 1/PRF. Since then the use of a fully coherent radar utilizing frequency agility, pulse to pulse, and the Digital Fourier Transform, has demonstrated a range resolution technique that does not require delay lines as did Ruttenberg's technique. The coherent pulses are fed to a DFT (usually the same size as the number of frequency shifts) and frequency is transformed into time (via the DFT) with intra-range resolution of the system following the same range resolution equation.

$$\Delta R = \frac{c}{2B}$$

where B is now the frequency agile bandwidth.

Gjessing, in his book "Adaptive Radar in Remote Sensing" shows that the amplitude spectrum of the scattered field is the Fourier transform of the delay function f(t). Thus, if the target is at some distance d, the delay function will oscillate with a period c/2d. Therefore, by the use of a multifrequency radar system, the resolution of the radar can be increased as the bandwidth of the agile radar increases. The complex Fourier transform will provide the true reference, while the amplitude only Fourier transform will provide the relative distances between the resolvable elements.

III. RADAR SIMULATION

The functional diagram of a polarimetric radar is shown in Figure 11. Functionally the model is a frequency agile coherent radar model. If a non-coherent radar model is desired the signal processor section can be modified. The frequency agile waveform selects the transmitter and coherent local oscillator frequency. The transmitter energy is split (coupled) to the dual polarized antenna with a $\pm 90^{\circ}$ phase shifter in the vertical channel, resulting in either right hand or left hand circular polarization. Zeroing one channel or the other results in horizontal or vertical polarization. Removing the phase shifter and adjusting the splitter results in slant polarization of any desired angle. If the cross coupling in the antenna section is large enough the result is an elliptical wave.

Energy reflected from the target area is received in both the horizontal and vertical antennas with cross coupling, and passed to the coherent Inphase (I) and Quadrature (Q) detectors, resulting in IF detected signals of horizontal I and Q, and vertical I and Q.

This radar simulation configuration allows maximum versatility by providing for circular, elliptical, and linear polarization transmission. Receiving horizontal and vertical with antenna cross coupling allows the signals of circular and elliptical, and horizonal and vertical, either coherent or non-coherent. The configuration shown in Figure 11 is not intended to imply prefered hardware configuration, but rather to depict a radar simulator which can be used to simulate a large number of pulsed polarimetric radars in order to evaluate proposed radars and signal processors.

A. Signal Processing

1. General

Outputs from the radar simulation (HI, HQ and VI, VQ) are input to the signal processing software where they are combined to form various types of received signals and the respective inverse Fourier transforms. The radar signals available from the the signal processor as plots are:

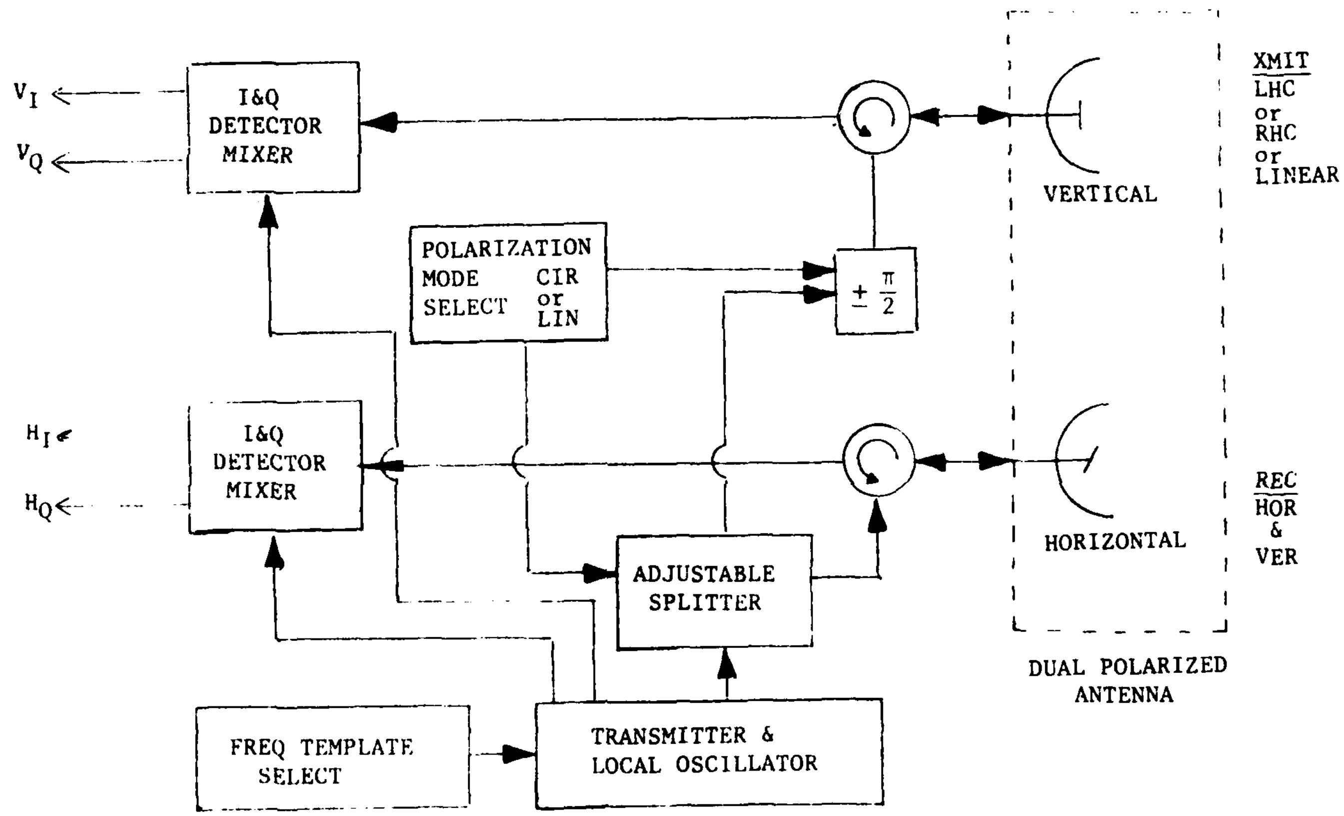
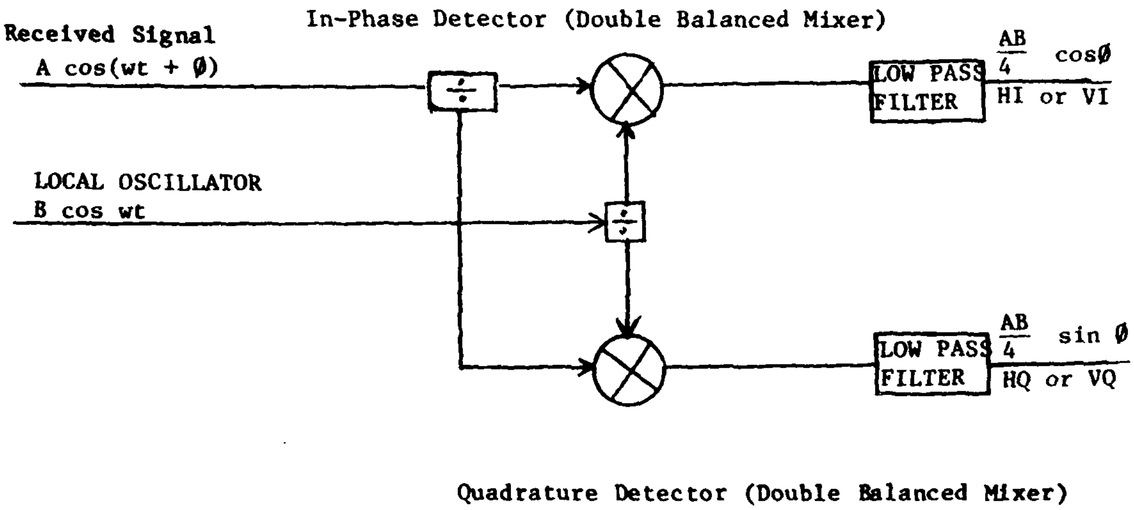


Figure 11. Radar configuration.

a. Peak Horizontal voltage
b. Peak Vertical voltage
c. Phase between Horizontal and Vertical
d. Peak Left Hand Circular (LHC) voltage
e. Peak Right Hand Circular (RHC) voltage
f. Phase between LHC and RHC
g. Scatterer Locations (inverse FFT's of coherent signals)
h. Scatterer Seperation (inverse FFT's of non coherent signals)
i. Phase plots of FFT's

2. Linear Polarizaton

Functionally the coherent horizontal and vertical signals are processed as shown in Figure 12. The resulting inphase and quadrature signals are then loaded into a complex array, and an inverse FFT is performed. The resulting lines represent the location of the scatterers relative to the leading edge of the radar range gate.



Horizontal Received Signal = HI+jHQ
Vertical Received Signal = VI+jVQ

Figure 12. Linear coherent detection block diagram.

Loading the real portion of the complex array with the amplitude magnitudes only, and performing an inverse FFT, results in lines that represent the separation of scatterers relative to each other. There is one line (neglecting sidelobes) for each combination of pairs of scatterers.

$$\text{No. lines} = \sum_{i=1}^{N} (N-i)$$

where N is the number of reflectors.

3. Circular Polarization

Figure 13 is a functional block diagram of a linear to circular tranformation. Inputting horizontal and vertical inphase and quadrature results in left and right hand circular polarized signals. This can be represented in matrix notation as:

$$\begin{bmatrix} RHc \\ LHc \end{bmatrix} = \frac{1}{\sqrt{2}} \begin{bmatrix} 1 & -j \\ 1 & j \end{bmatrix} \begin{bmatrix} H \\ V \end{bmatrix}$$

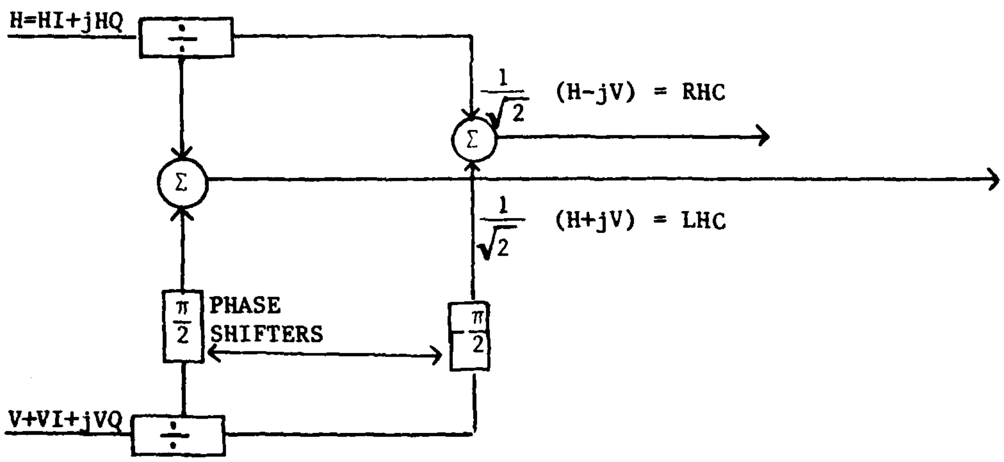


Figure 13. Block diagram of linear to circular polarization converter.

Loading the resulting RHC or LHC into a complex array, and performing an inverse FFT, results in lines that represent the location of scatterers relative to the leading edge of the radar range gate.

Loading the real portion of the complex array with the amplitude magnitudes only, and performing an inverse FFT, results in lines that represent the seperation of scatterers relative to each other.

IV. SIMULATION ULITIZATION

A. General Simulation Outputs

Figures 14 through 35 are the 22 output plots of the simulation. Four received amplitudes (Horizontal, Vertical, LHC and RHC) are plotted as a function of the transmit frequency. The header data presented at the top of each plot define the radar operating parameters used in the calculations. All plot headers for each input parameter set are identical. The phase angle between received Horizontal and Vertical or RHC and LHC is plotted as a function of transmit frequency and is the angle Beta discussed in paragraph 2.2. The remaining 16 plots are inverse FFT's, amplitude and phase, plotted as a function of intra-range gate resolution. The FFT amplitude plots labeled I&Q provide scatterer location from the leading edge of the range cell while the plots labeled peak amplitude provide scatterer separation depending on whether the amplitude data were loaded into the FFT as complex I&Q or as real amplitude only. FFT's were loaded in ascending order with the received signal from the lowest transmit frequency in location one.

B. Antenna Isolation

Utilizing the simulator program, and varying the amount of one way antenna polarization isolation, can reveal the effects of isolation on the polarimetric outputs of a system. This is exampled by Figures 28 through 32 which show the LHC and RHC scatterer locations for a four target array with 30 dB one way polarization isolation. Figures 36 and 37 present the same conditions with 10 dB isolation for comparison. Comparing these plots one can observe the cross coupling from one channel to the other.

While this example is presented for LHC and RHC output it is obvious that the other outputs of the simulation may also be examined. Antenna isolation effects on horizontal or vertical outputs, in either the coherent or non-coherent mode, as well as other combinations of transmitter and receiver polarization configurations, can be examined.

C. Signal to Noise Ratio

System noise effects on polarimetric outputs can be examined in two ways: first, by increasing target range (reducing signal strength); second, by increasing the receiver noise figure (increase system noise). Examples of these are given in Figures 17 and 21 (horizontal and vertical scatterer locations for a greater than 30 dB signal to noise ratio), and Figures 38 and 39 (for a signal to noise ratio of 8 dB).

Inputting a clutter model and varying the system noise will allow examination of the effects of the clutter to noise problem on signal processing. System noise can be increased by elevating the receiver noise figure.

D. Signal to Clutter

The utilization of the simulator program to explore the effects of clutter on signal detection will be highly dependent upon the target and clutter models used. A model for clutter in polarimetric form that has been truly verified has yet to be developed. Therefore, in order to demonstrate the use of the program the following example will be used: a contrived target model of one and one half meters radar length, made up of five reflectors randomly spaced, and having a radar cross section of five square meters each (Figures 40 through 43); clutter made up of fifty randomly selected location, orientation, and type spaced reflectors of 0.1 square meters each. This example has a total signal to clutter ratio of 25/5, or 7 dB, and is shown in the horizontal and vertical location plots in Figures 44 and 47. Figures 48 through 51 show the same configuration with the clutter cross section increased to one square meter per reflector. This represents a signal to clutter ratio of -3.0 dB (25/50).

V. CONCLUSIONS AND RECOMMENDATIONS

A digital simulation has been developed to investigate various aspects of a frequency agile, polarimetric pulsed radar system. While the simulation is not all inclusive and will undoubtedly be refined and updated for years to come, it is a useful tool for evaluating both hardware and software effects on

the next generation of radars. The simulation validation was performed by comparison with an operational radar. The validation has been excluded as the data were acquired from a contractor's IR&D radar. Any government agency desiring more information relative to the validation should contact the authors at AV 746-4061.

Major limiting factors to simulation results are the target and clutter scattering models which remain basically undefined at this time. It is recommended that all models and data in the future be done in scattering matrix format so that the entire radar signature will be available for future radar hardware and simulator designers. Without such data and validated models the radar system analyst and designer will continue to suffer from the so called "Sedenquist Effect"; that is, put two radar engineers in a room and say the word "clutter"; return years later and they will still be trying to define and agree as to what clutter is.

Future plans for the polarimetric radar simulator include the addition of doppler, tracking errors, jamming, attenuation back scatter due to weather, and realistic model development.

This simulation does not include cross range positional effects of scatterers. All cross range scatterer positions within the antenna beamwidth are collapsed to a single radial range bin. The inclusion of doppler will provide the second "cross-range" dimension for two dimensional analysis.

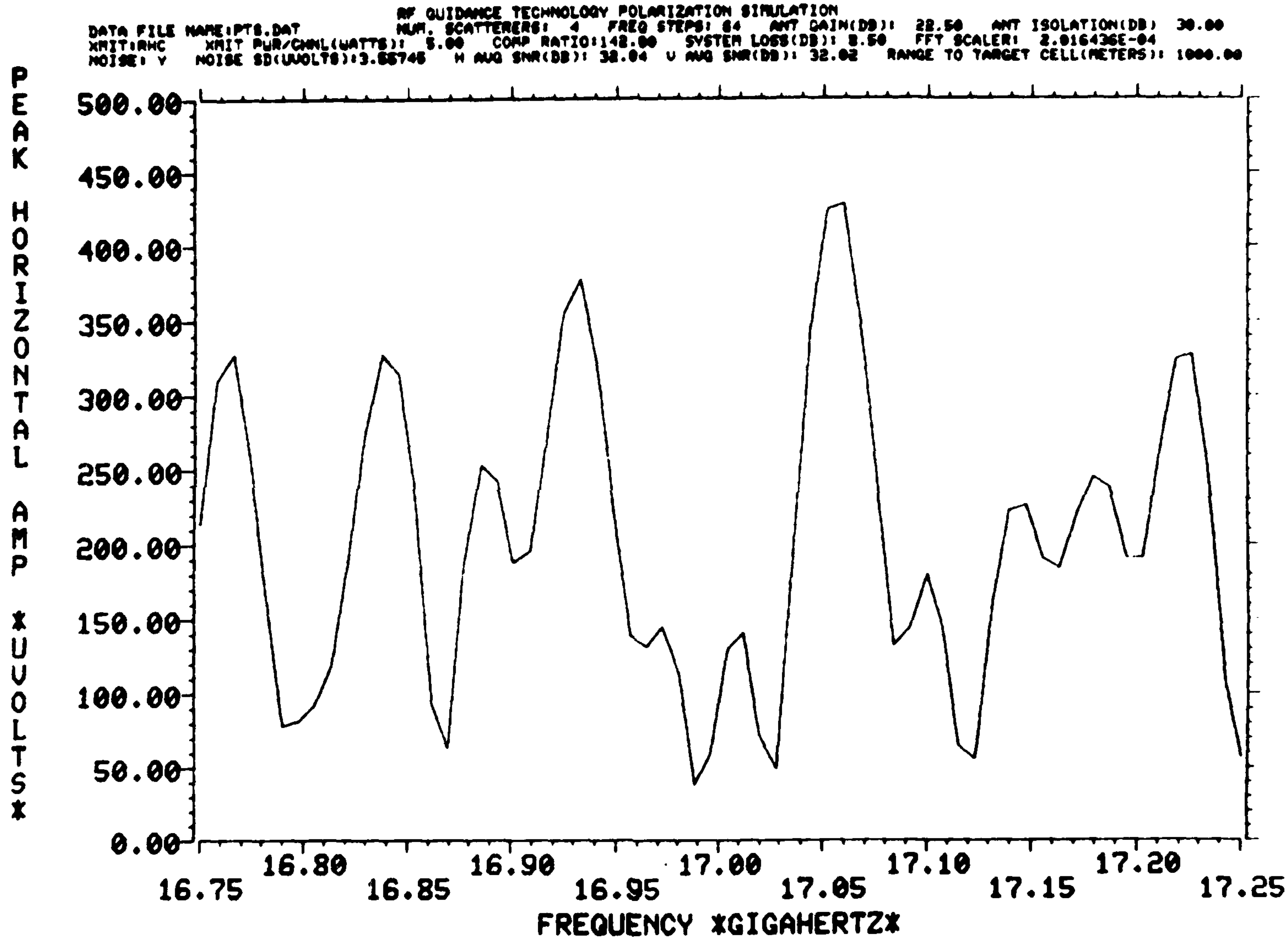


Figure 14. Peak horizontal amplitude vs. frequency at 30 dB antenna isolation.

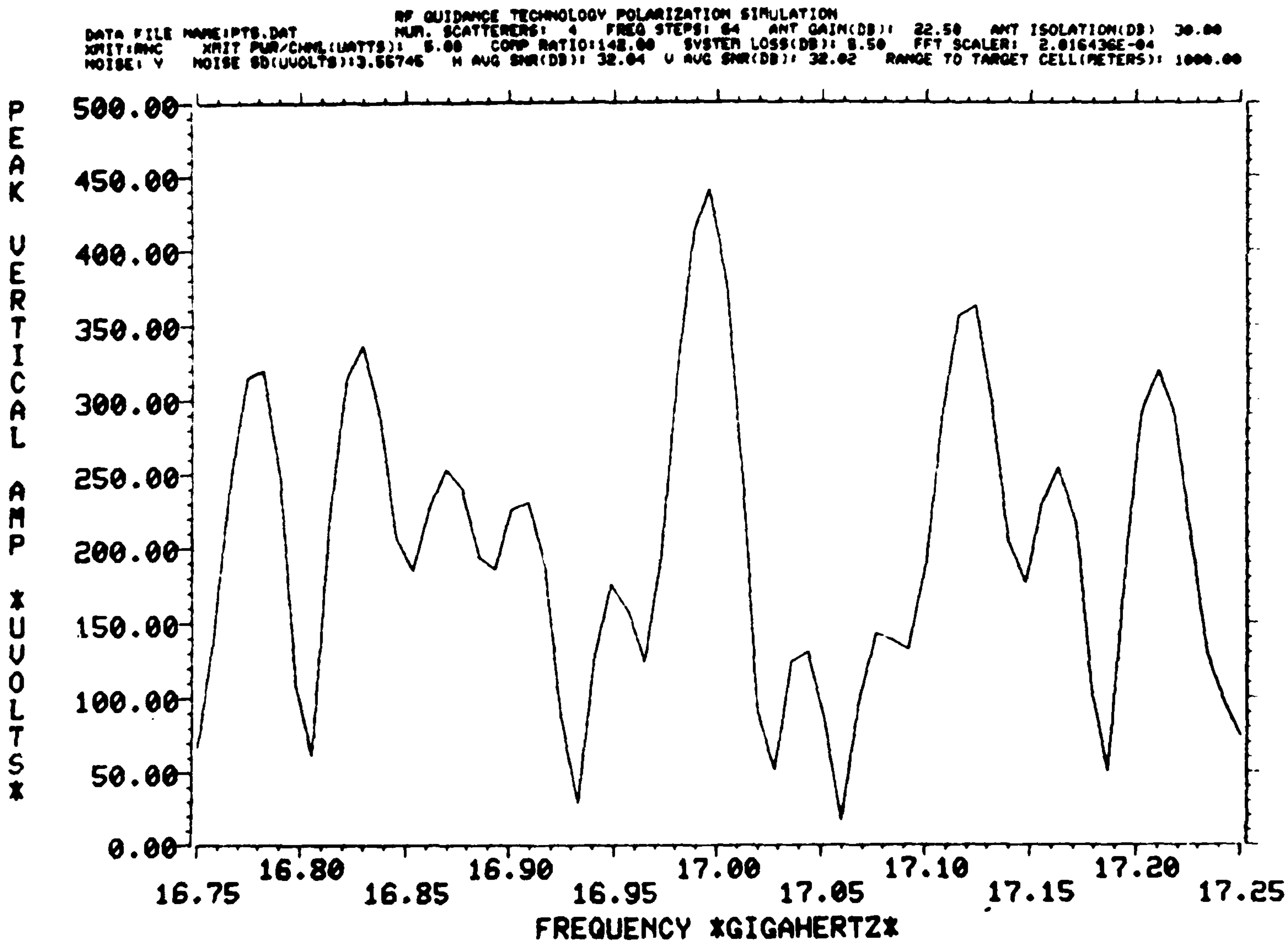


Figure 15. Peak vertical amplitude vs. frequency at 30 dB antenna isolation.

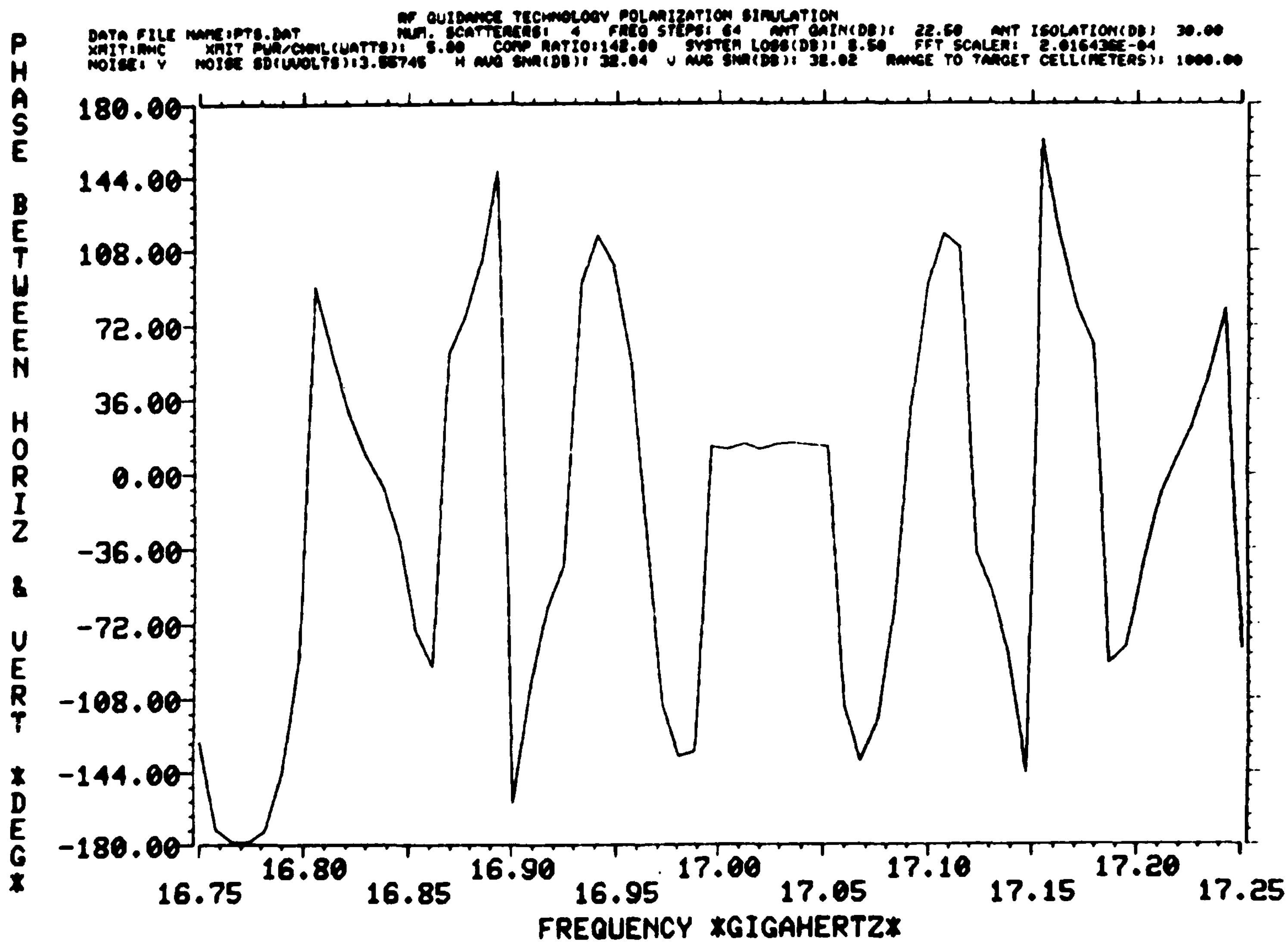


Figure 16. Phase angle between horizontal and vertical at 30 dB antenna isolation.

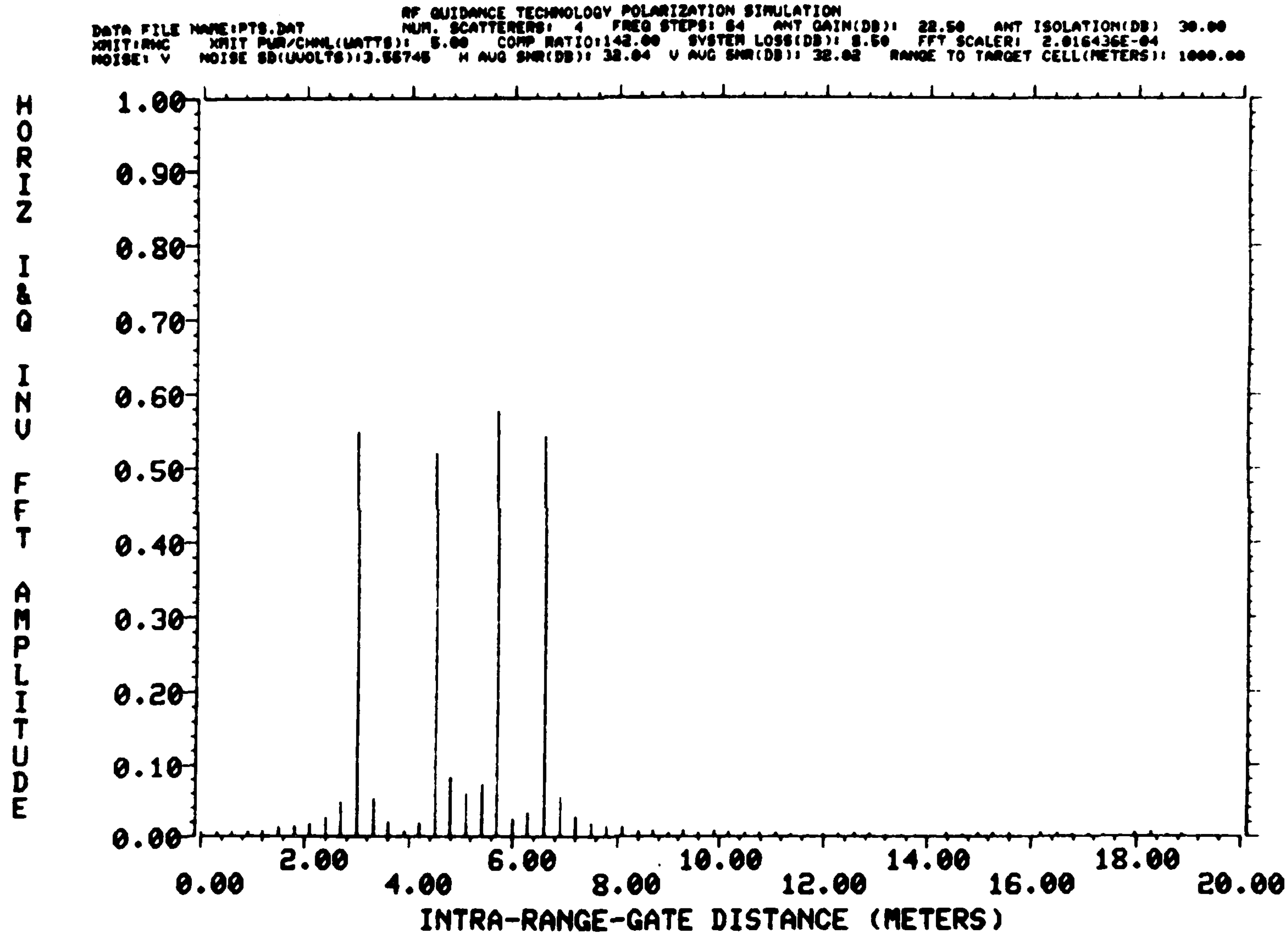


Figure 17. Inverse FFT of horizontal I&Q at 30 dB antenna isolation.

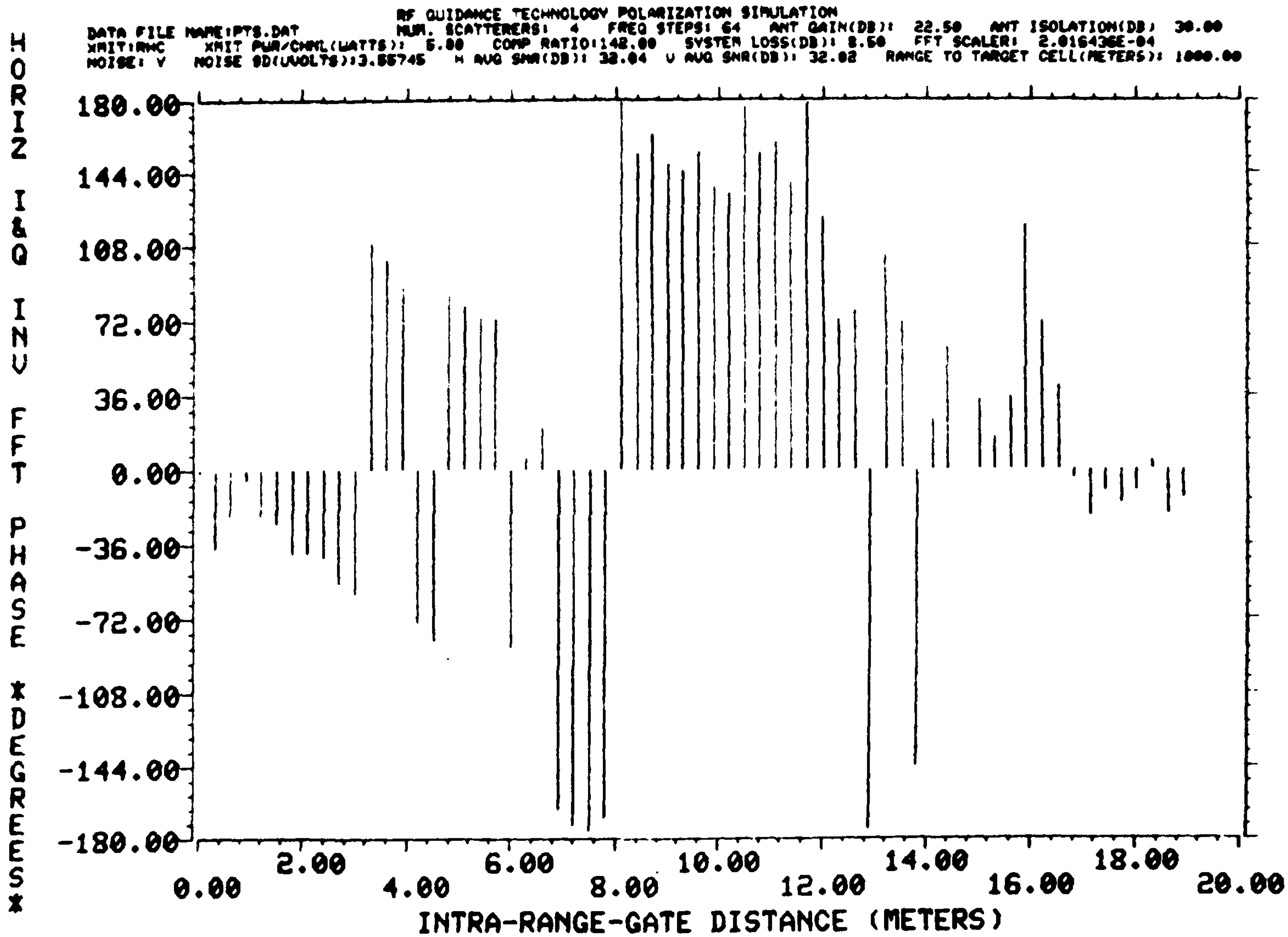


Figure 18. Inverse FFT phase angle for horizontal I&Q at 30 dB antenna isolation.

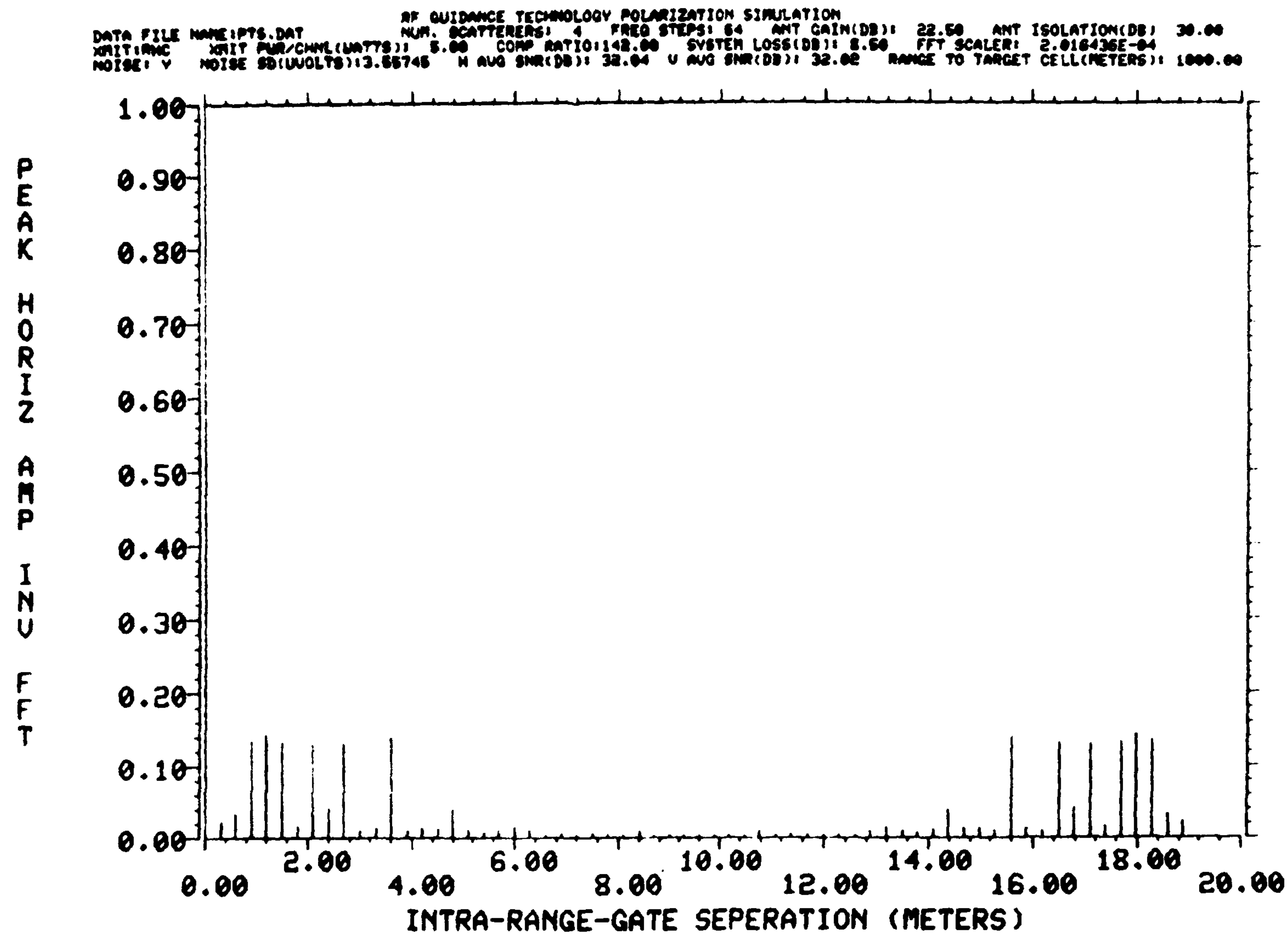


Figure 19. Inverse FFT of peak horizontal amplitude at 30 dB antenna isolation.

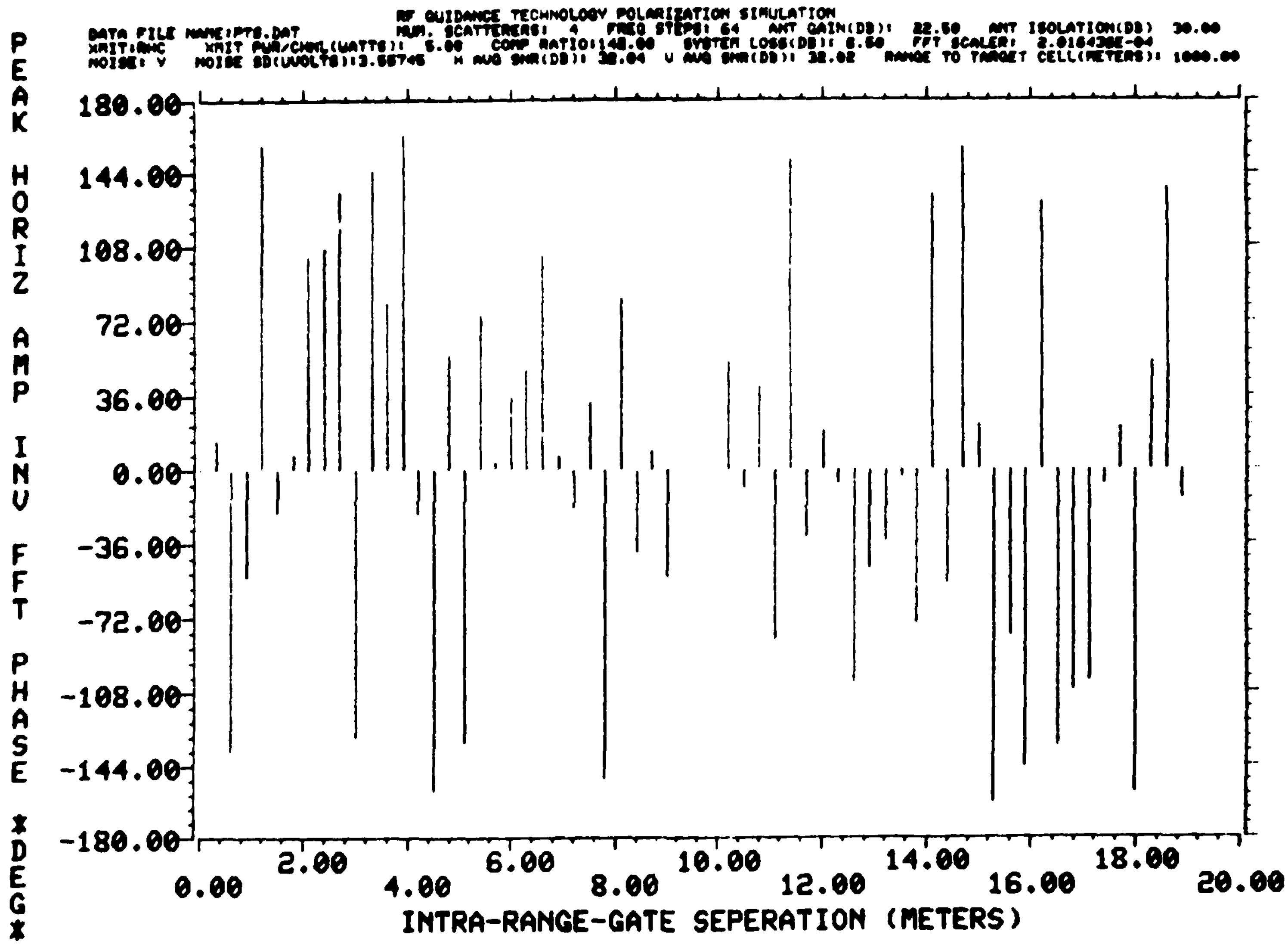


Figure 20. Inverse FFT phase angle of peak horizontal amplitude at 30 dB antenna isolation.

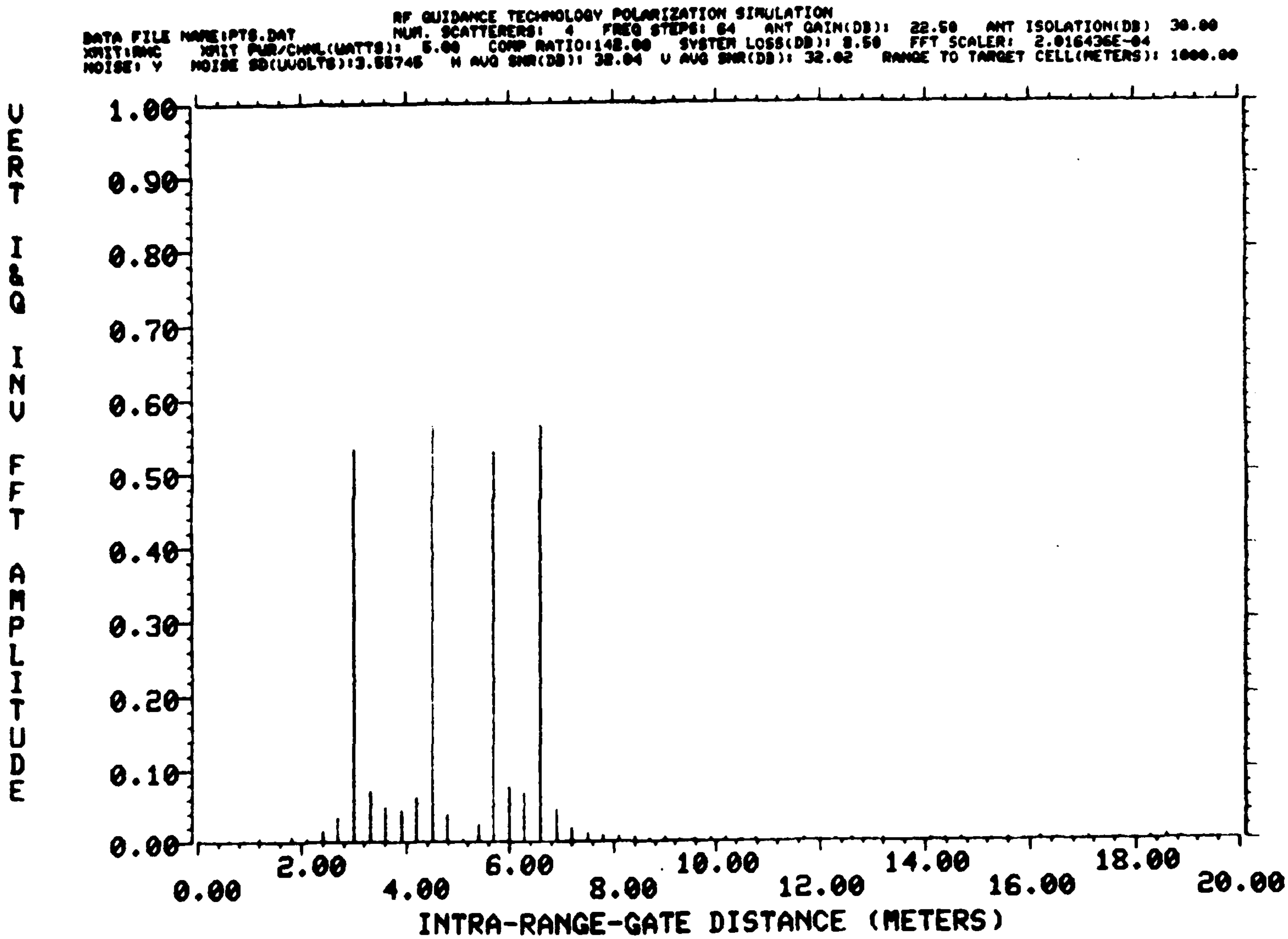


Figure 21. Inverse FFT of vertical I&Q at 30 dB antenna isolation.

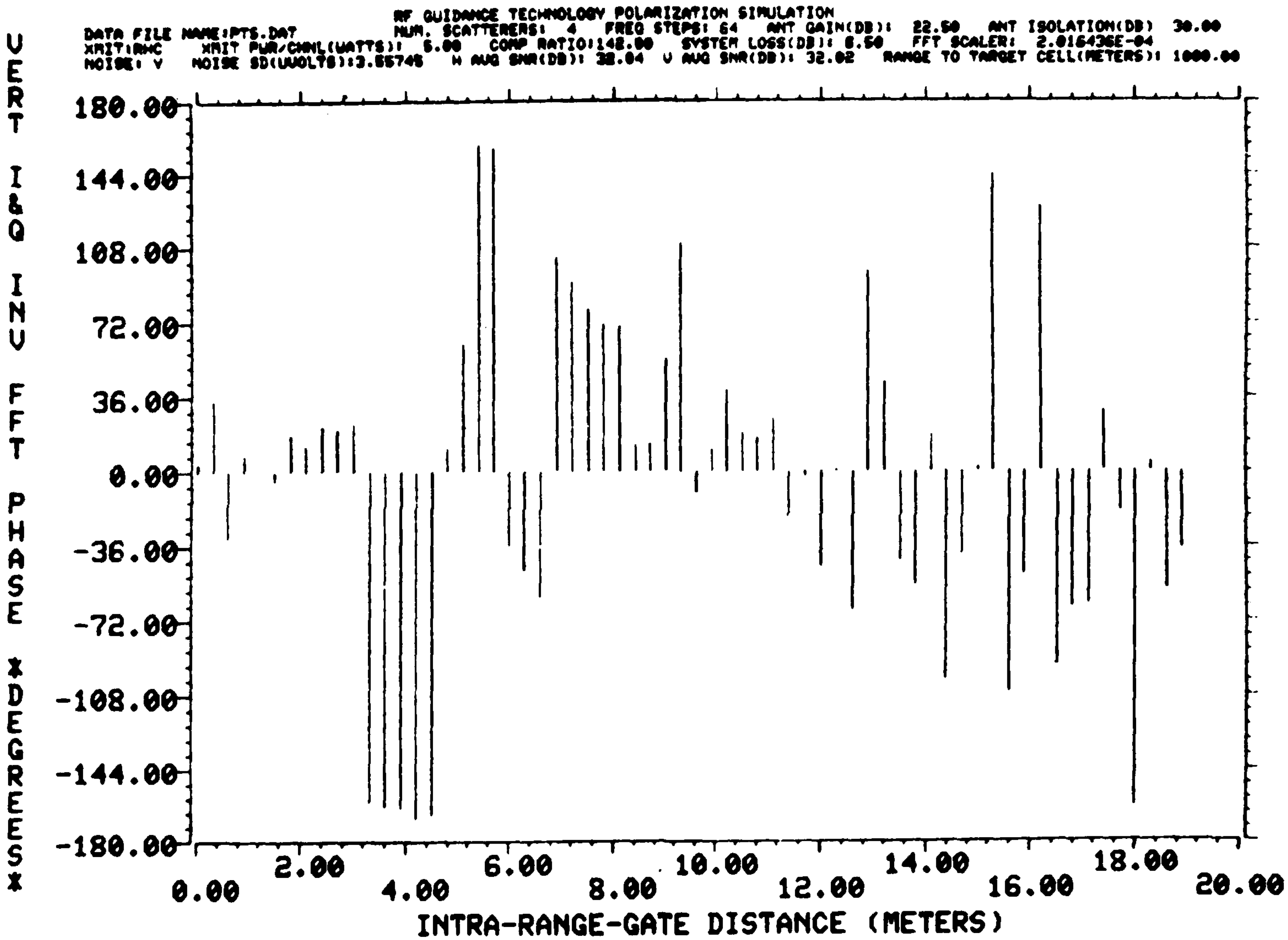


Figure 22. Inverse FFT phase angle for vertical I&Q at 30 dB antenna isolation.

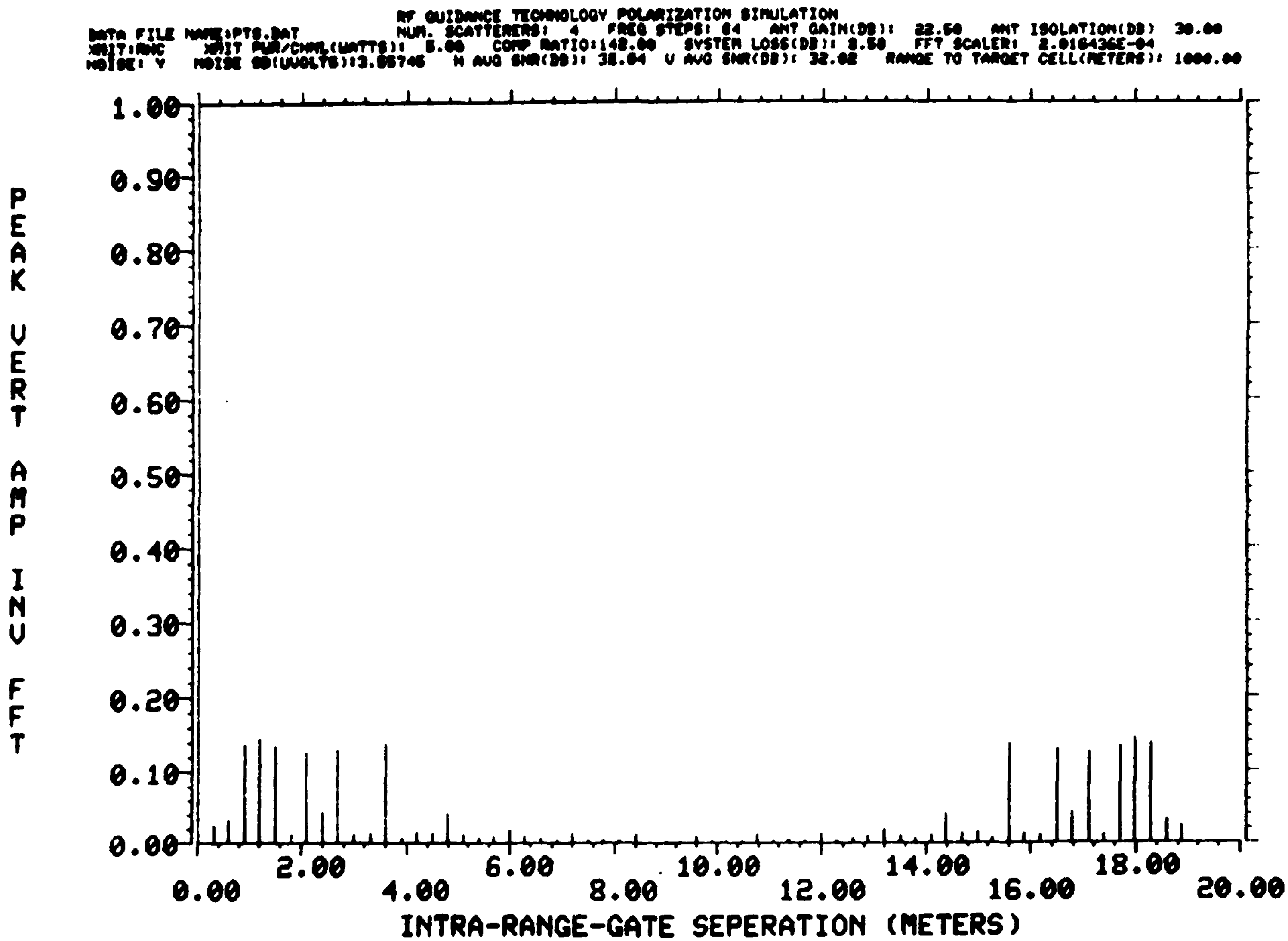


Figure 23. Inverse FFT of peak vertical amplitude at 30 dB antenna isolation.

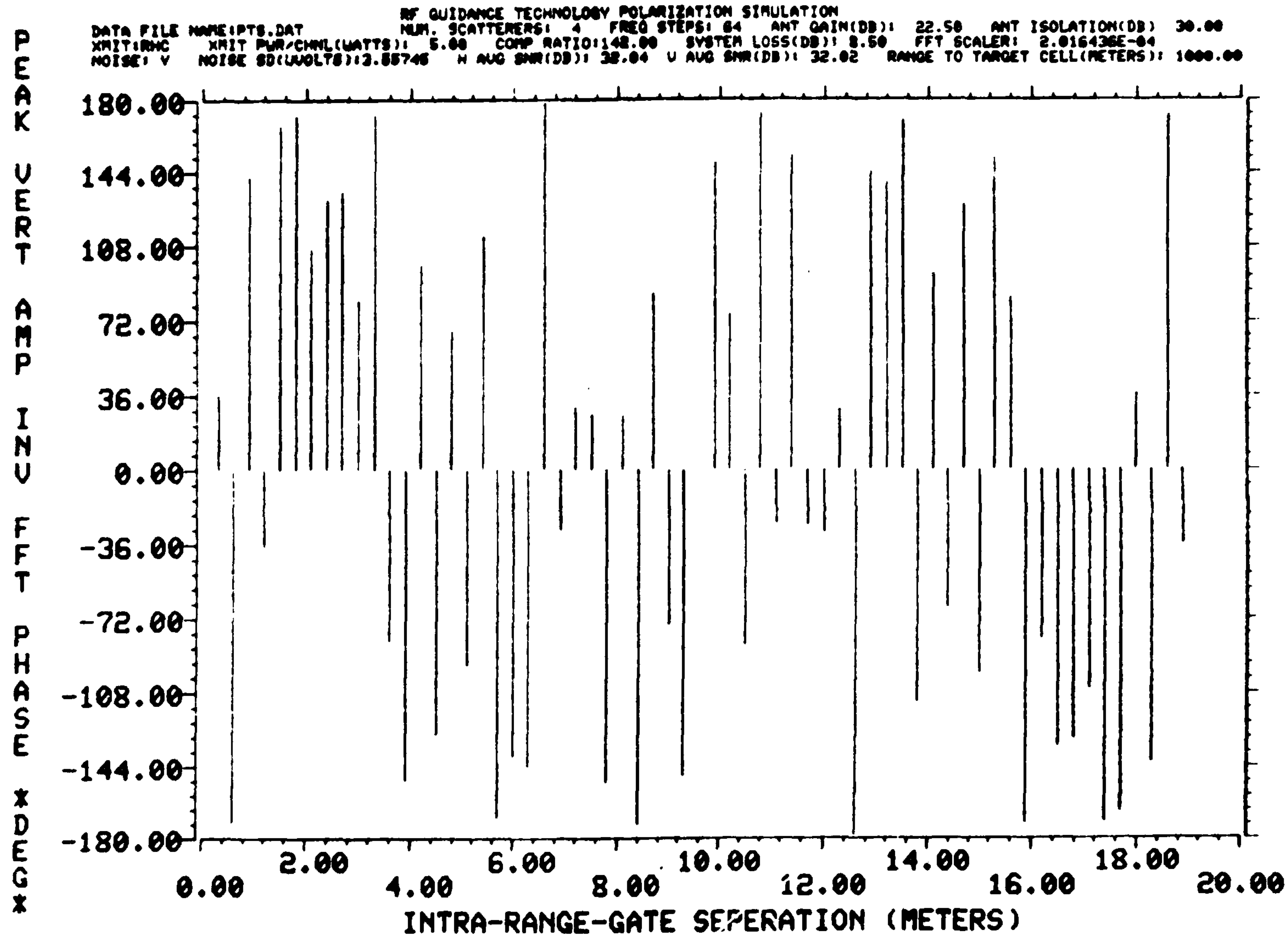


Figure 24. Inverse FFT phase angle of peak vertical amplitude at 30 dB antenna isolation.

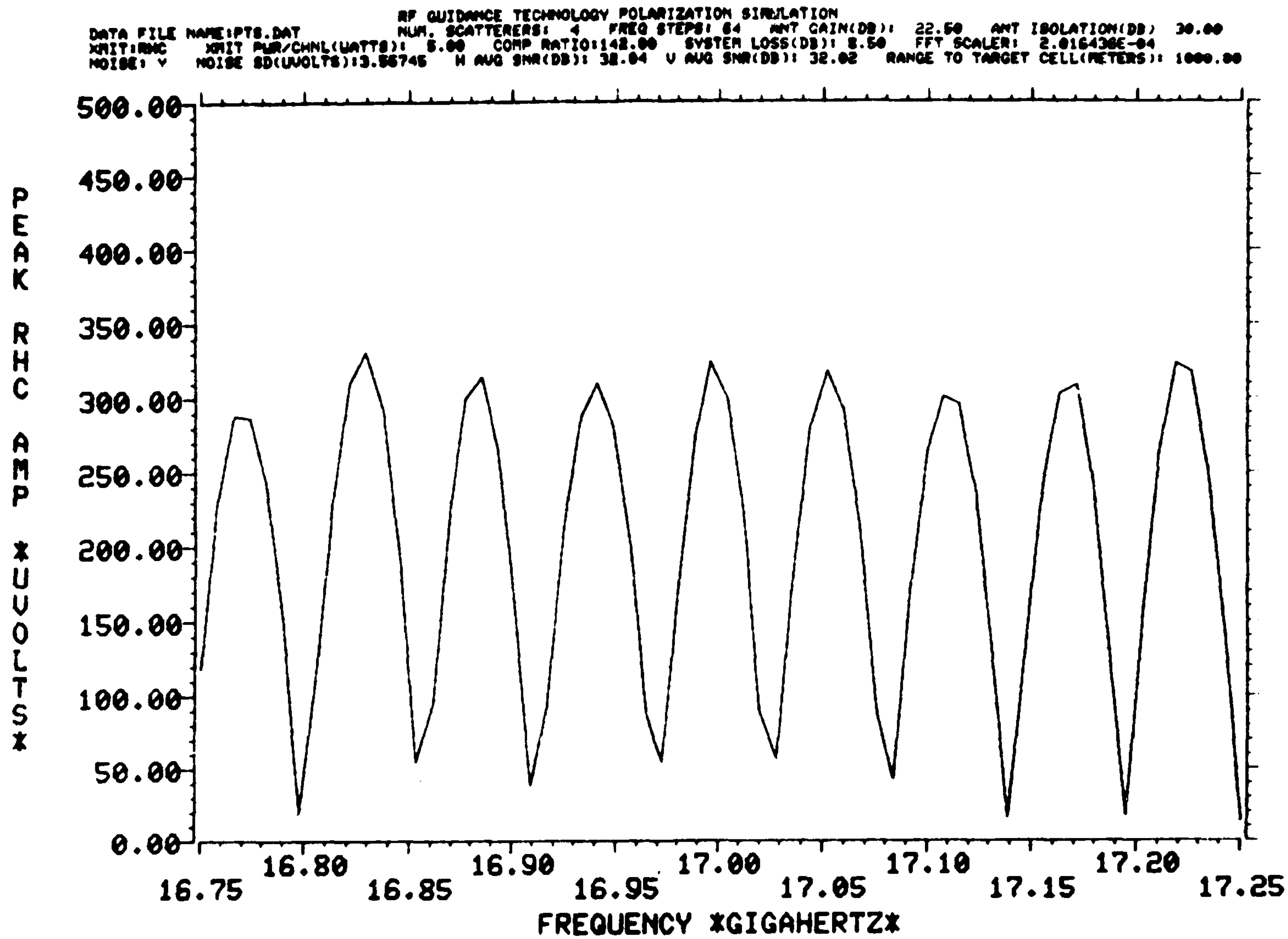


Figure 25. Peak RHC amplitude vs. frequency at 30 dB antenna isolation.

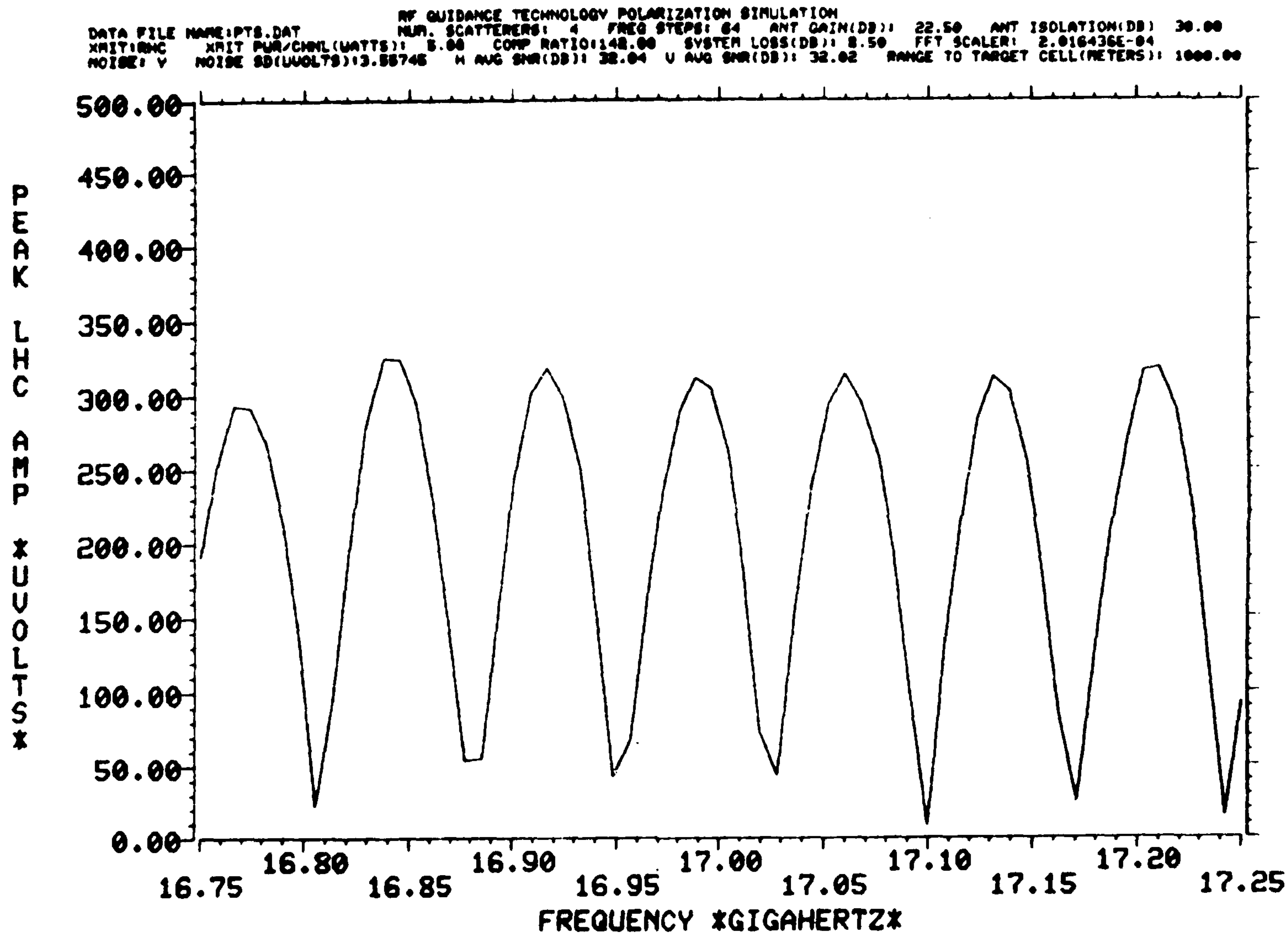


Figure 26. Peak LHC amplitude vs. frequency at 30 dB antenna isolation.

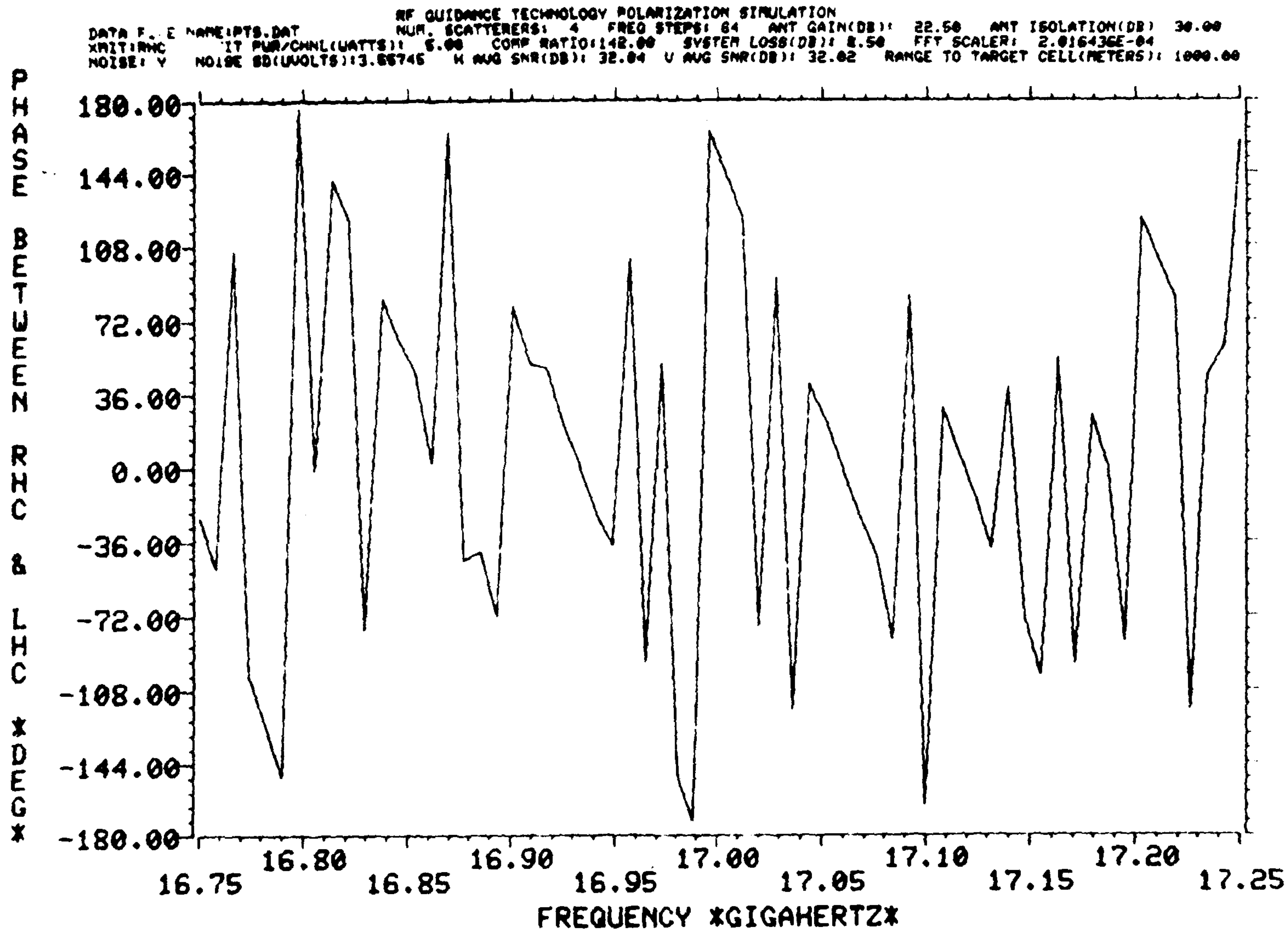


Figure 27. Phase angle between RHC and LHC at 30 dB antenna isolation.

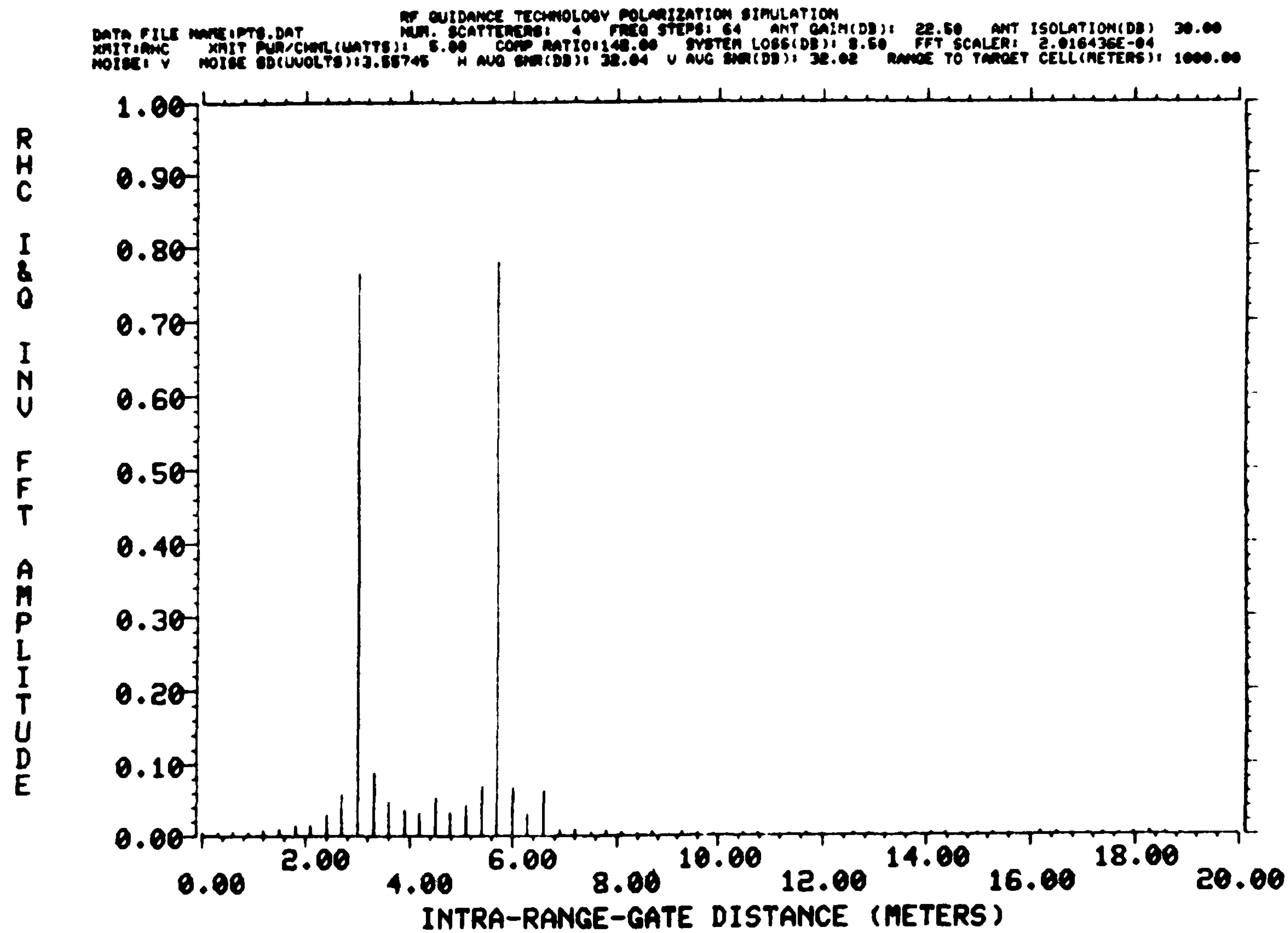


Figure 28. Inverse FFT of RHC I&Q at 30 dB antenna isolation.

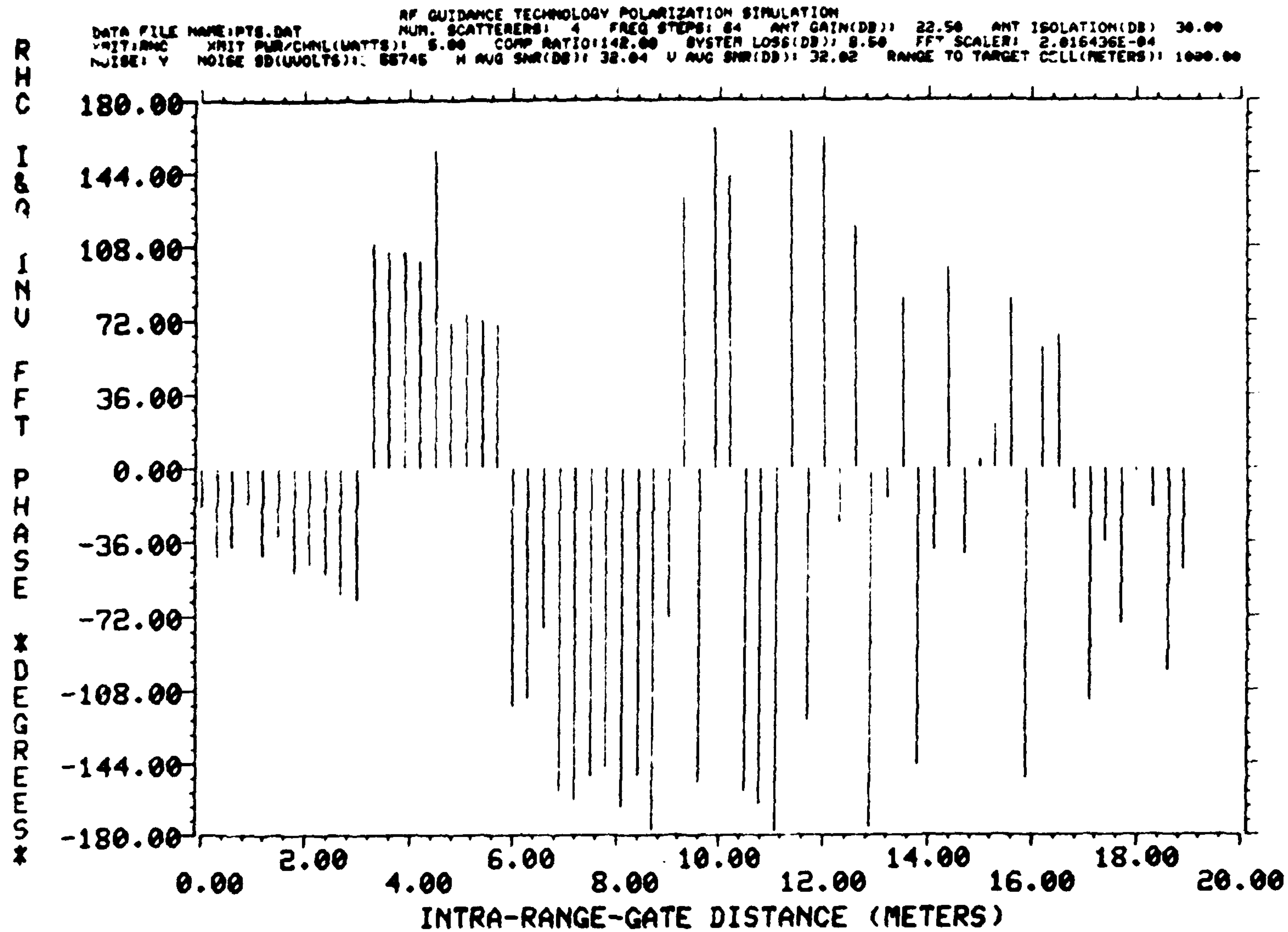


Figure 29. Inverse FFT phase angle for RHC I&Q at 30 dB antenna isolation.

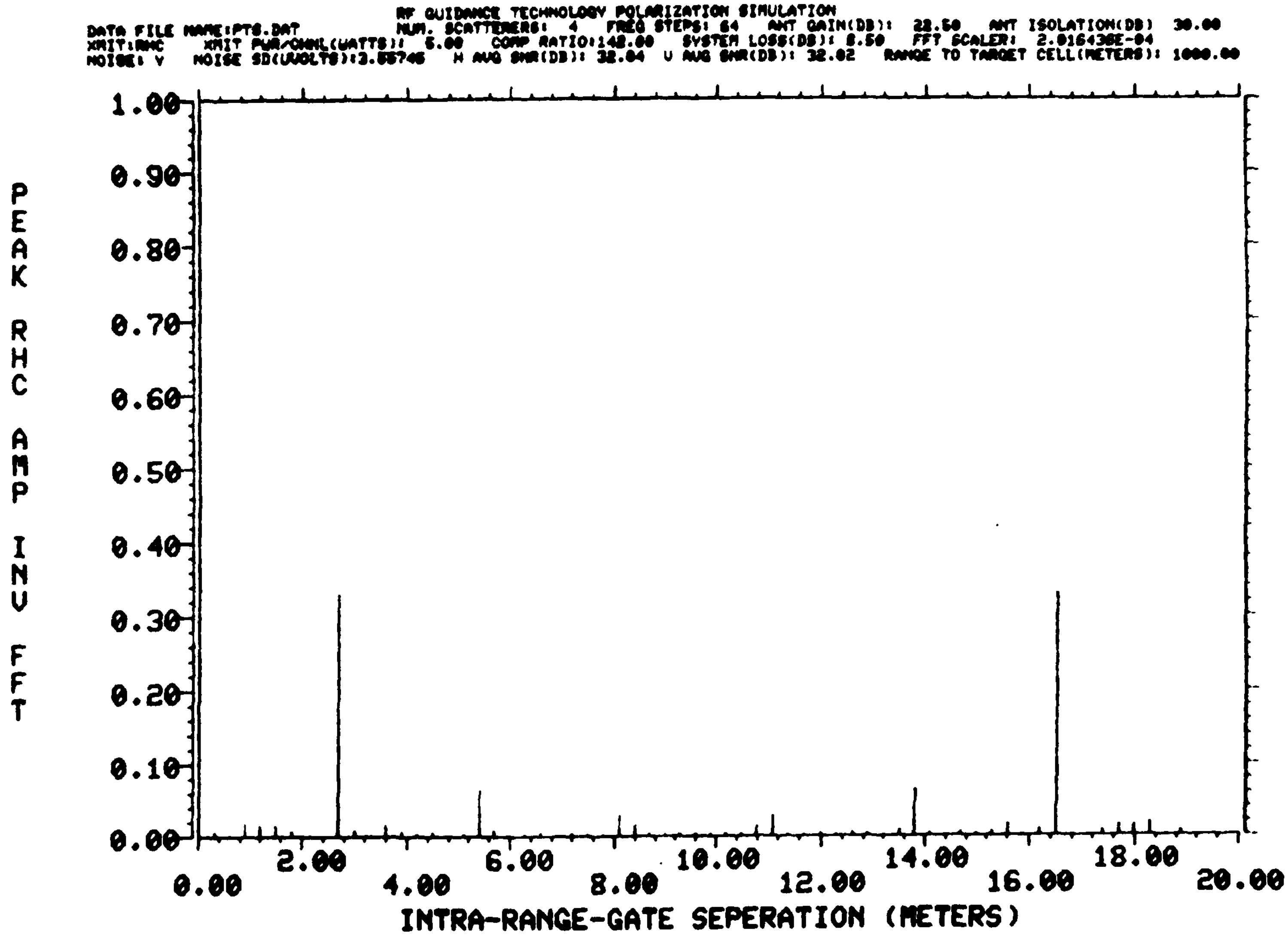


Figure 30. Inverse FFT of peak RHC amplitude at 30 dB antenna isolation.

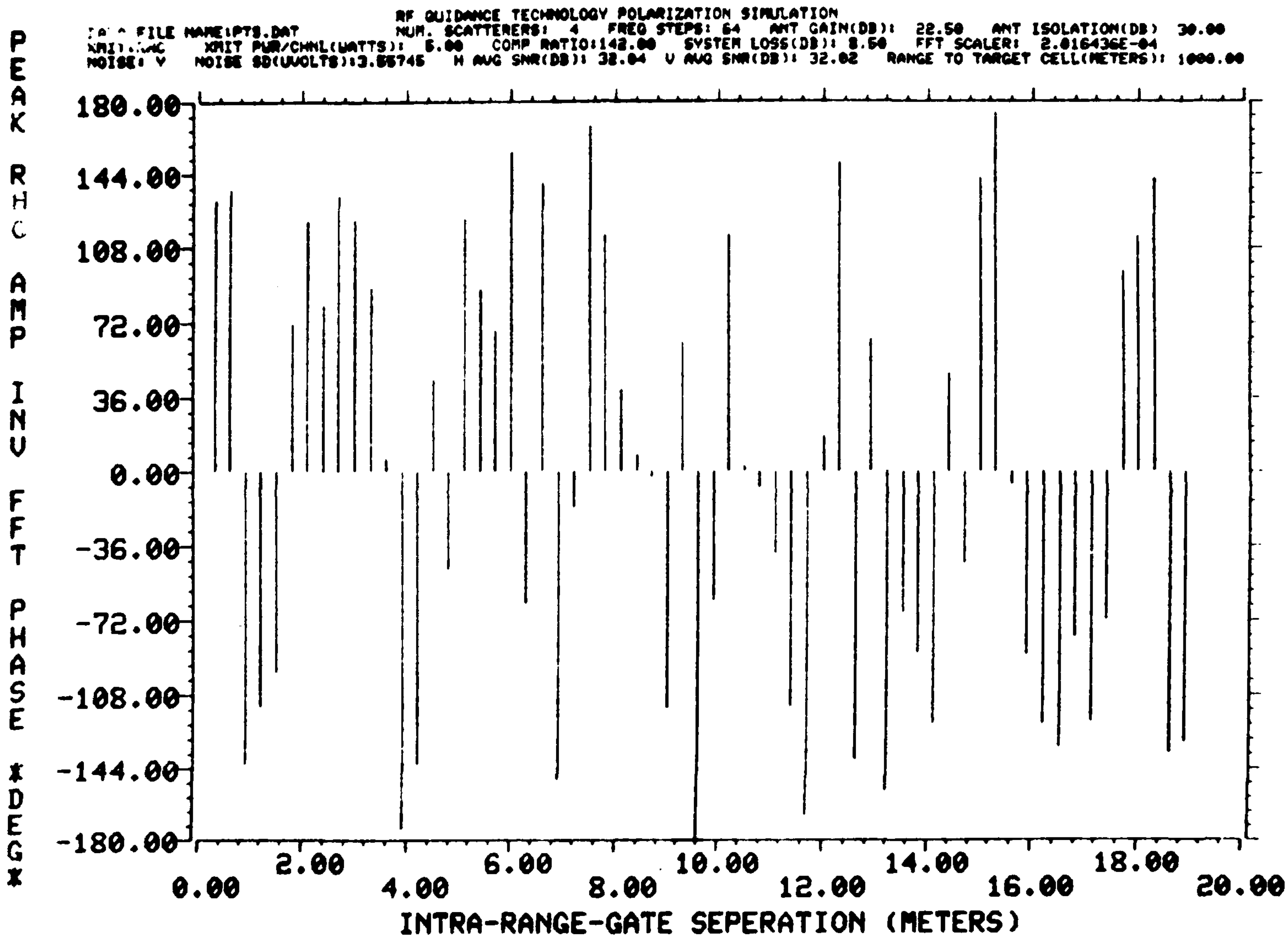


Figure 31. Inverse FFT phase angle of peak RHC amplitude at 30 dB antenna isolation.

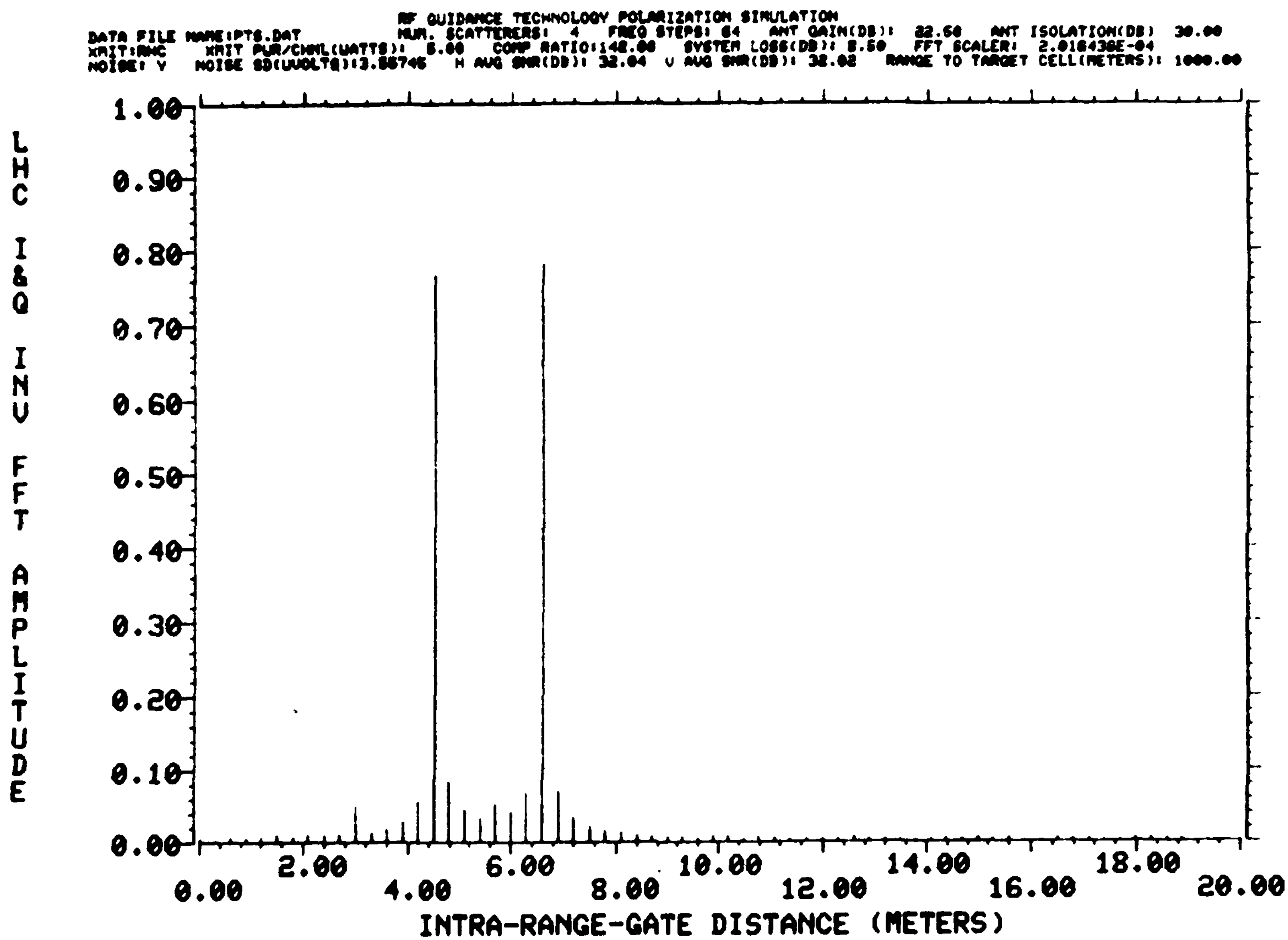


Figure 32. Inverse FFT of LHC I&Q at 30 dB antenna isolation.

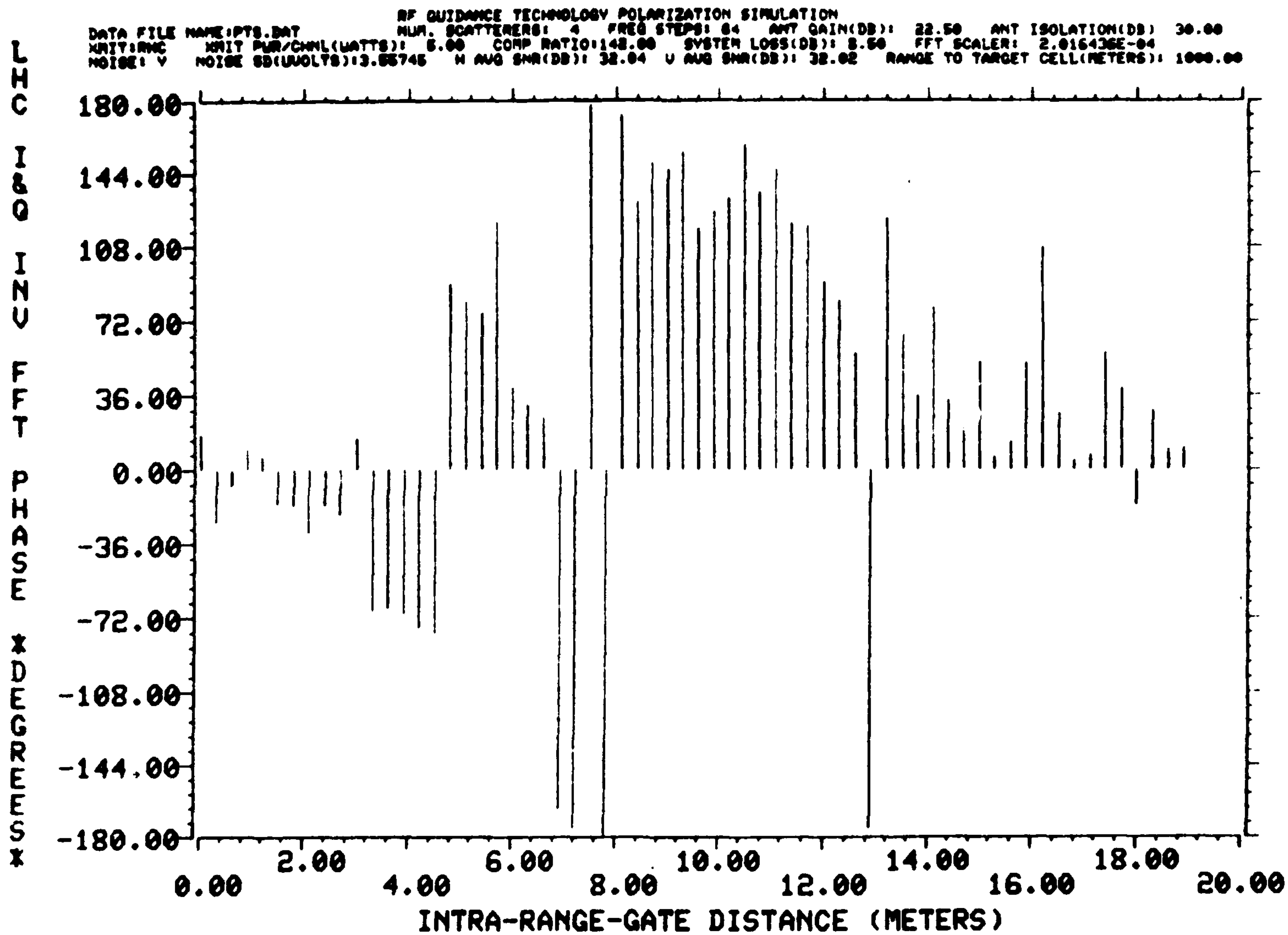


Figure 33. Inverse FFT phase angel for LHC I&Q at 30 dB antenna isolation.

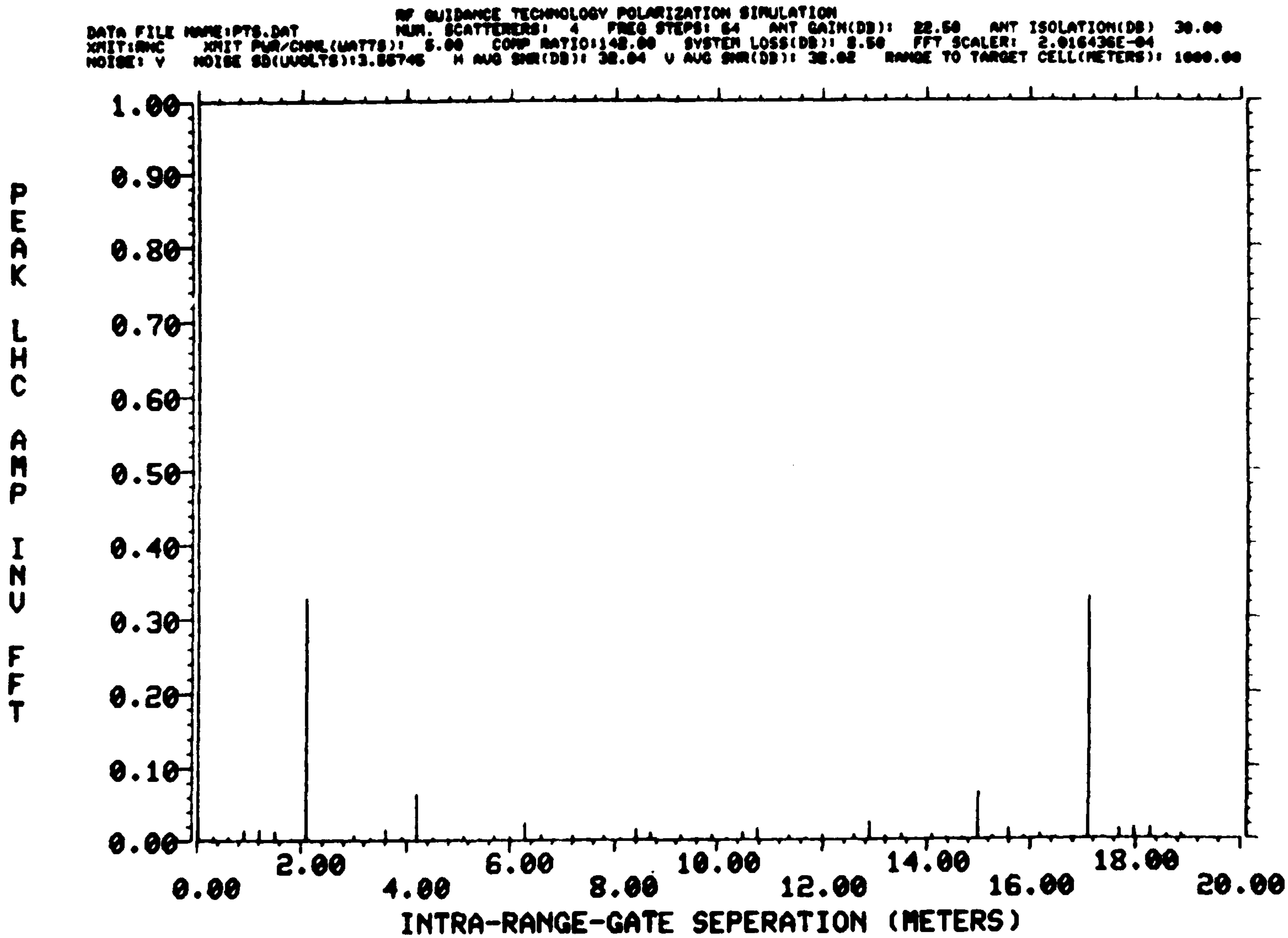


Figure 34. Inverse FFT of peak LHC amplitude at 30 dB antenna isolation.

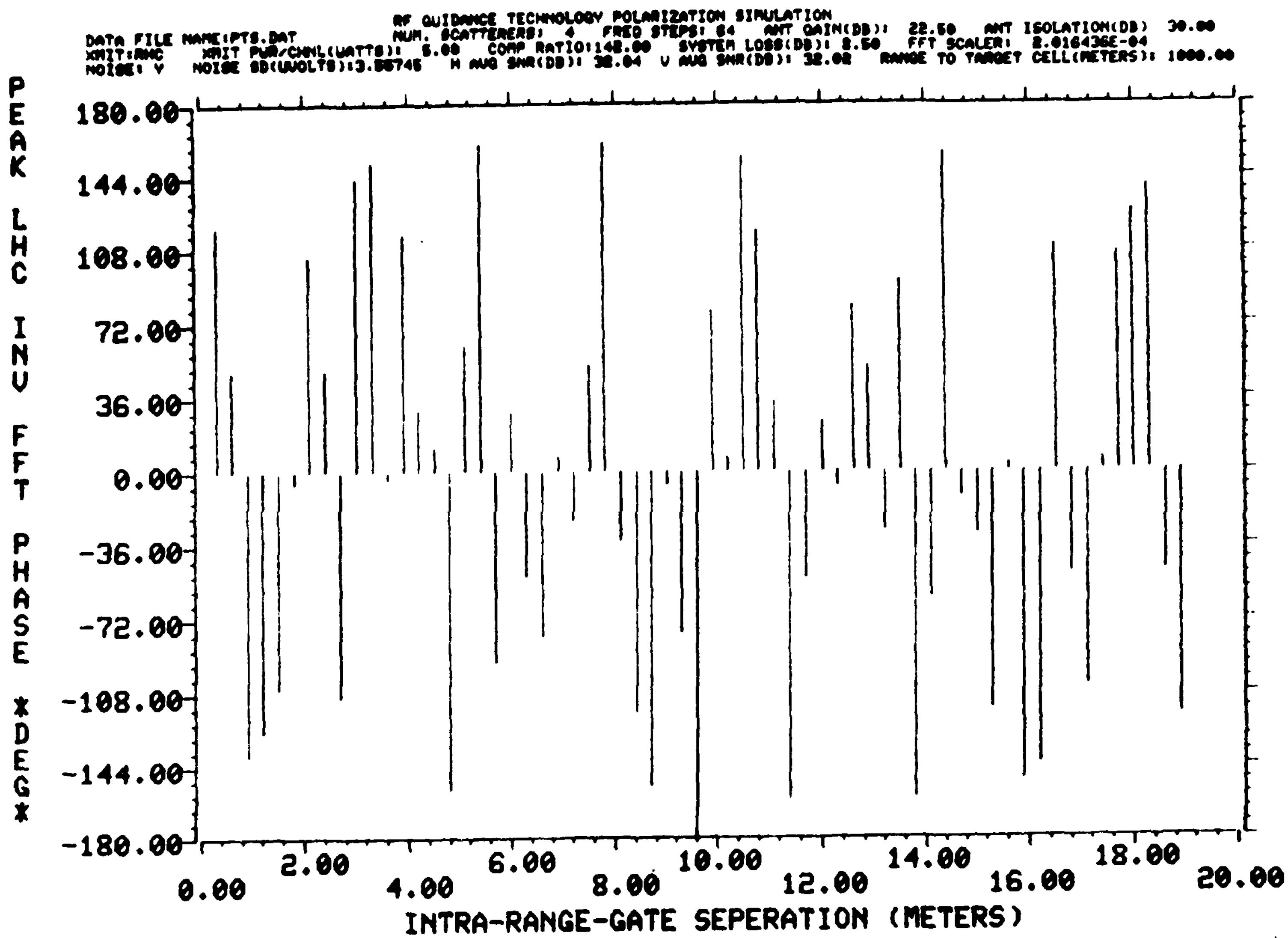


Figure 35. Inverse FFT phase angle of peak LHC amplitude at 30 dB antenna isolation.

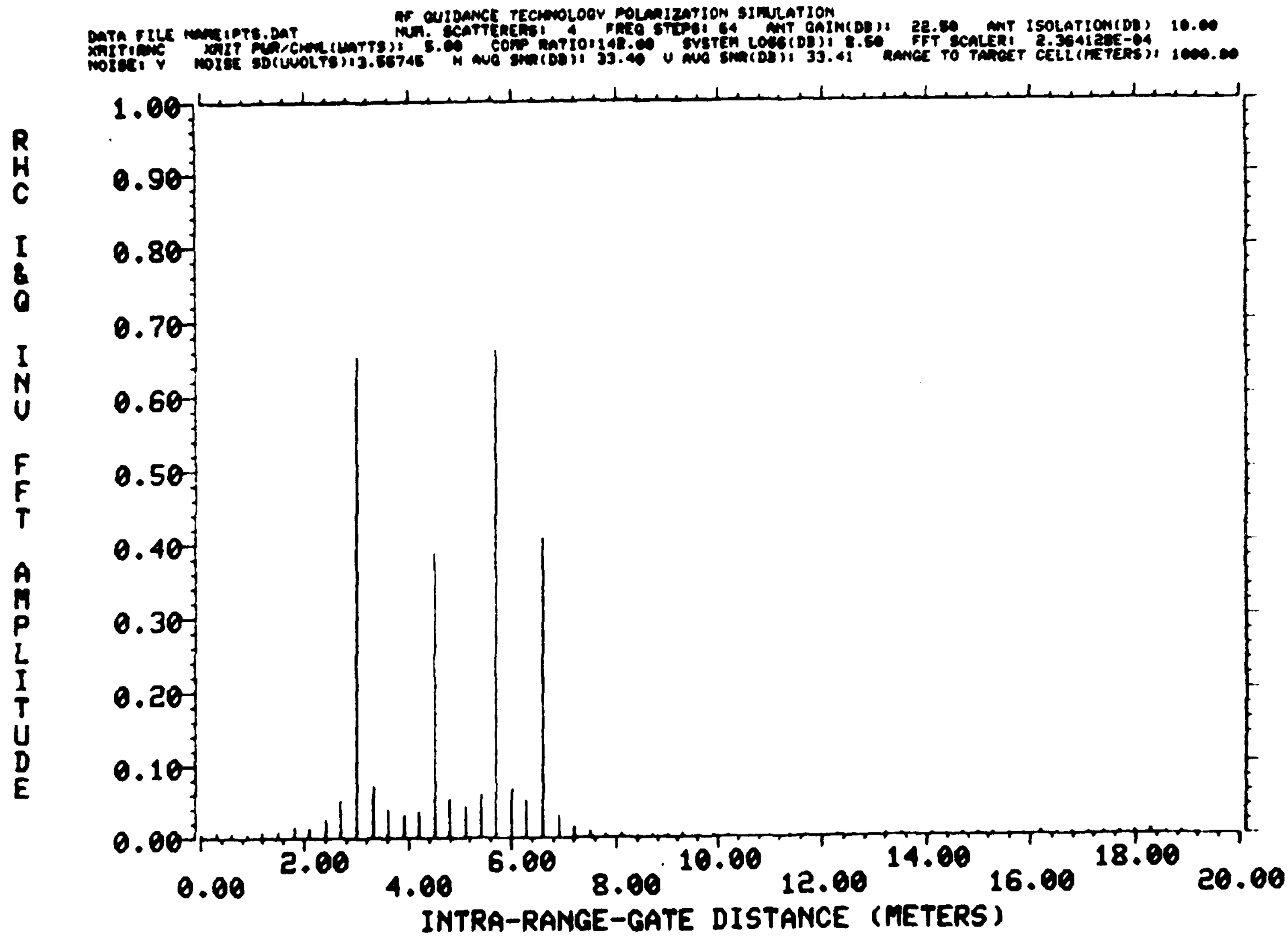


Figure 36. Inverse FFT of RHC I&Q at 10 dB antenna isolation.

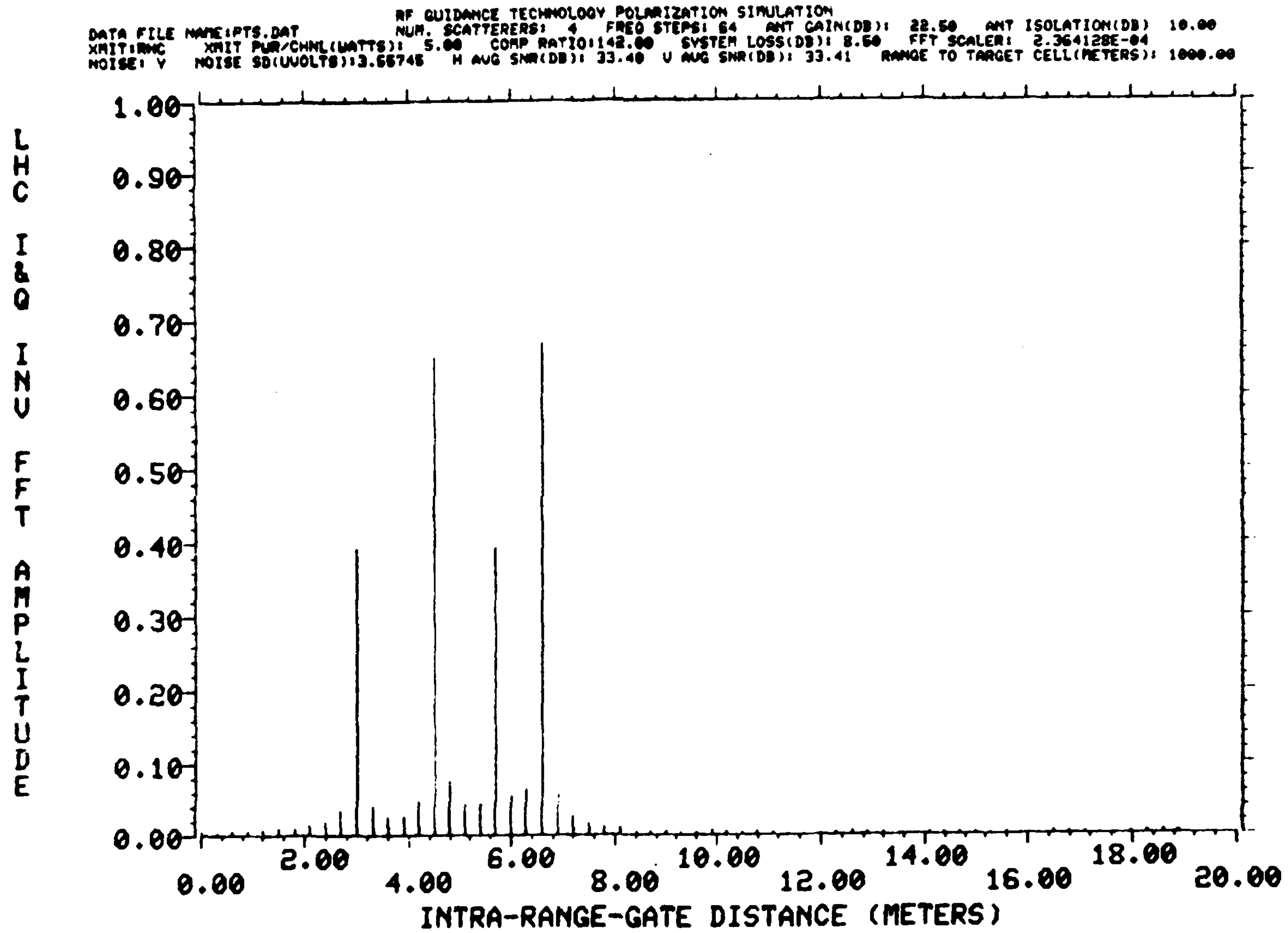


Figure 37. Inverse FFT of LHC I&Q at 10 dB antenna Isolation.

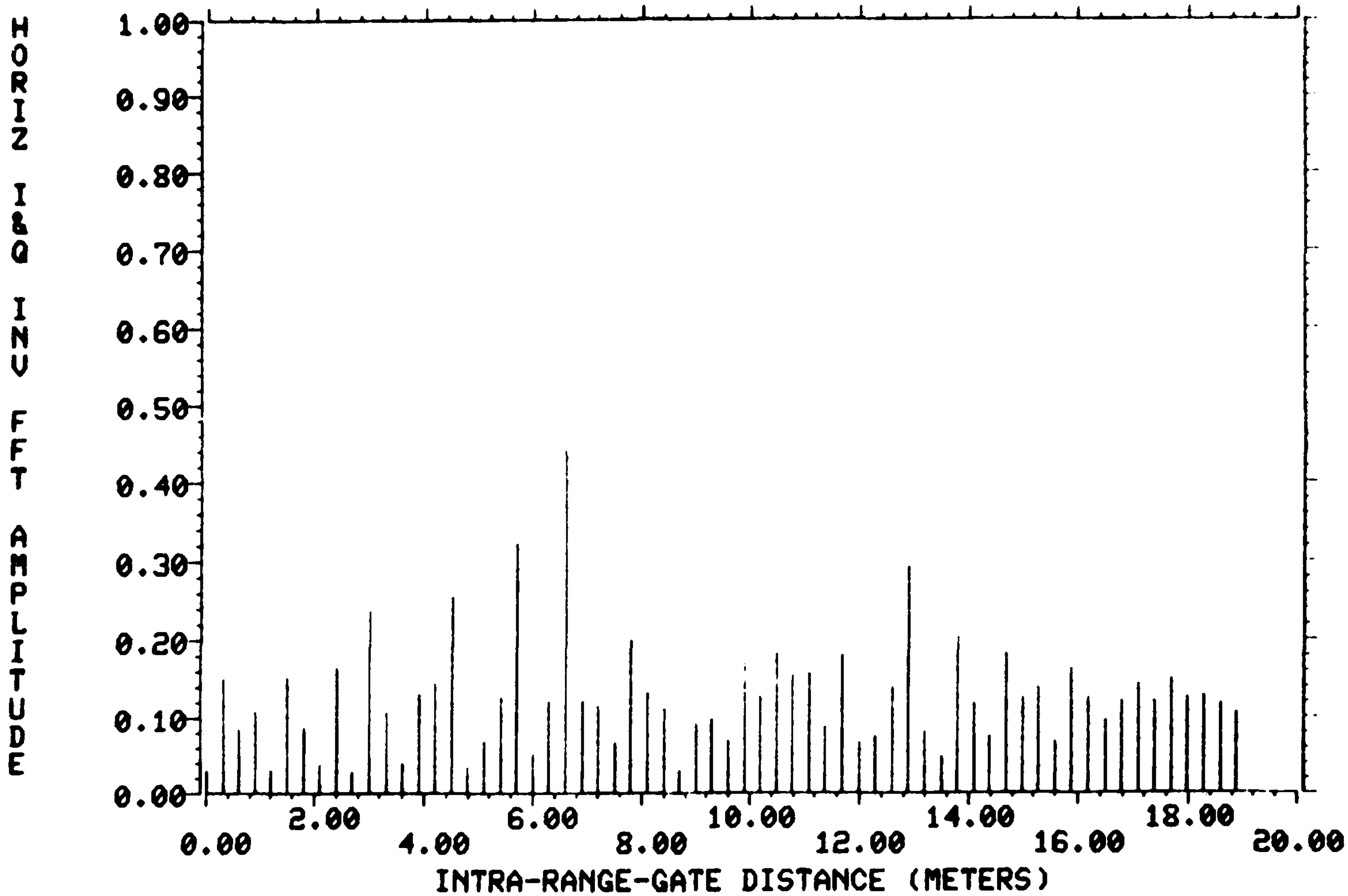


Figure 38. Inverse FFT of horizontal I&Q, single pulse S/N equal -8 dB.

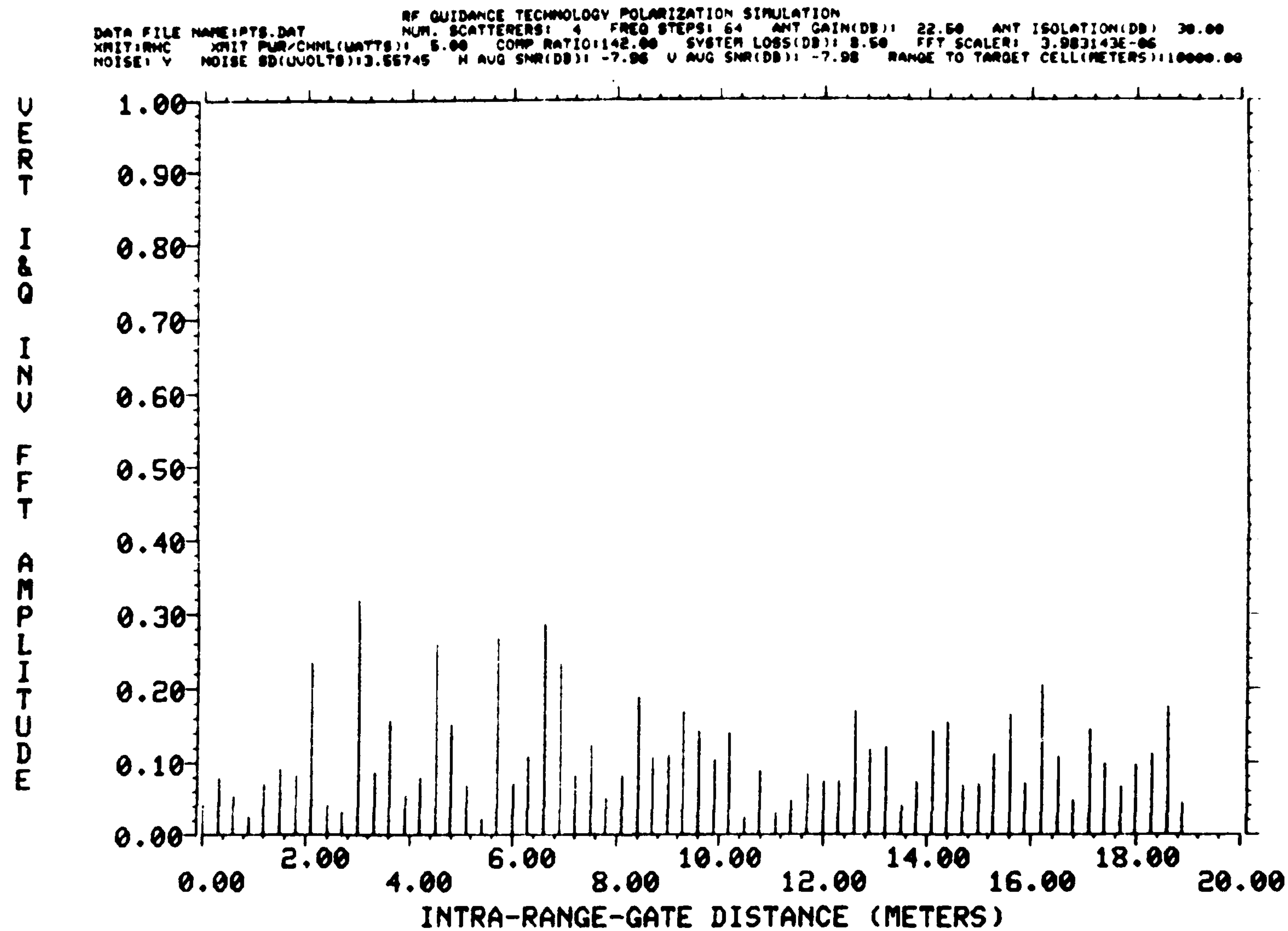


Figure 39. Inverse FFT of vertical I&Q, single pulse S/N equal -8 dB.

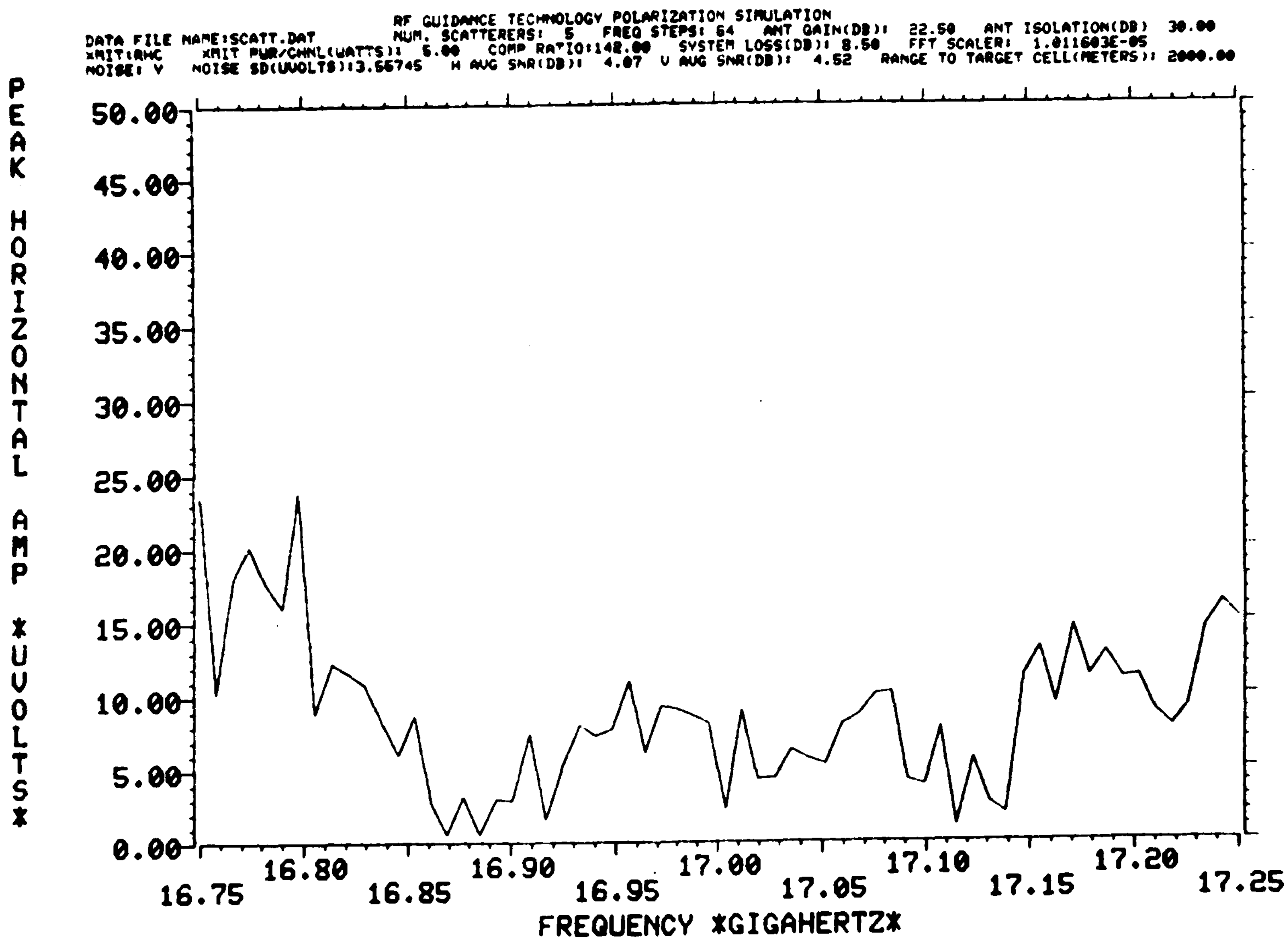


Figure 40. Peak horizontal voltage for target model only.

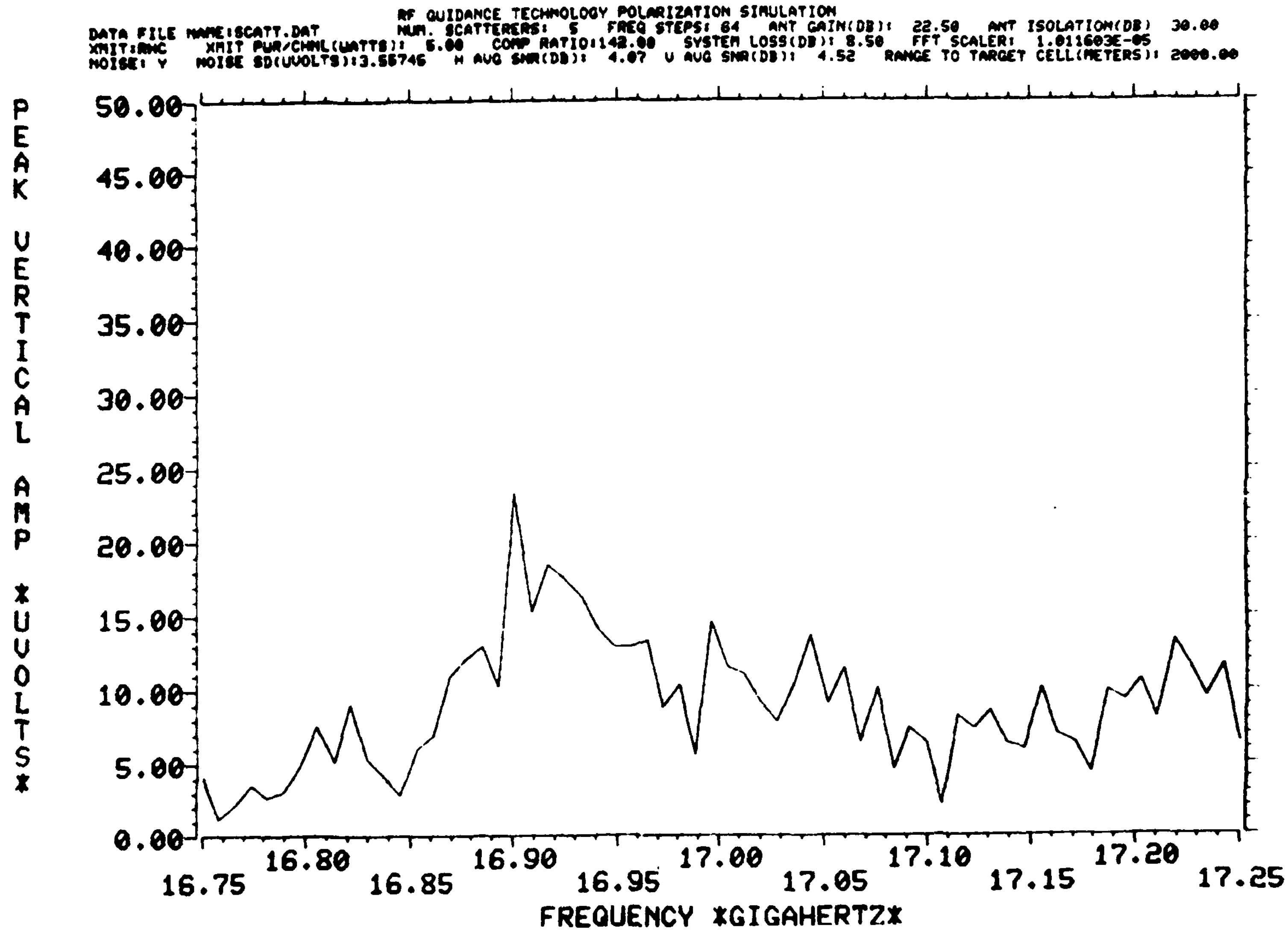


Figure 41. Peak vertical voltage for target model only.

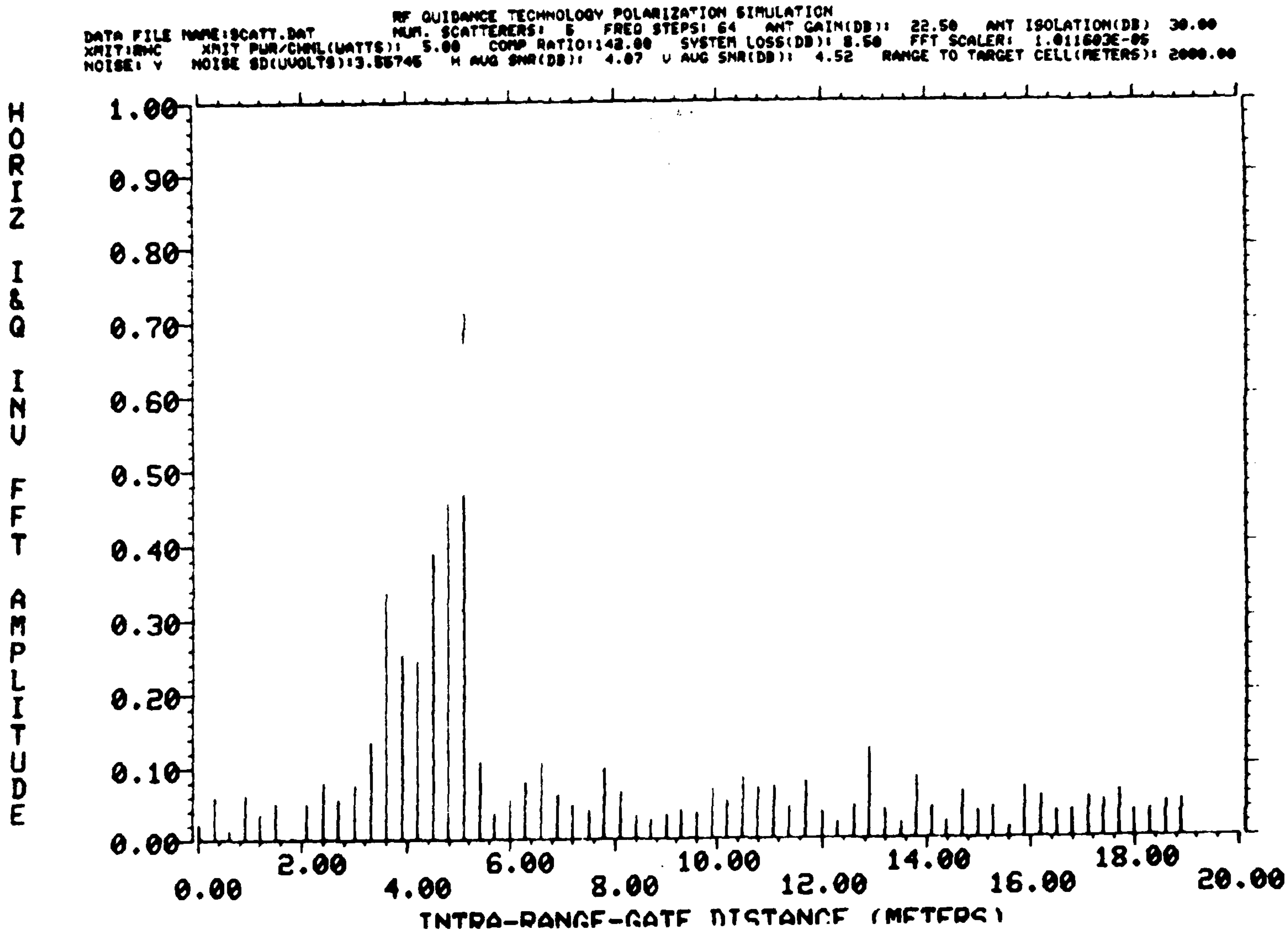


Figure 42. Inverse FFT of horizontal I&Q for tank model only.

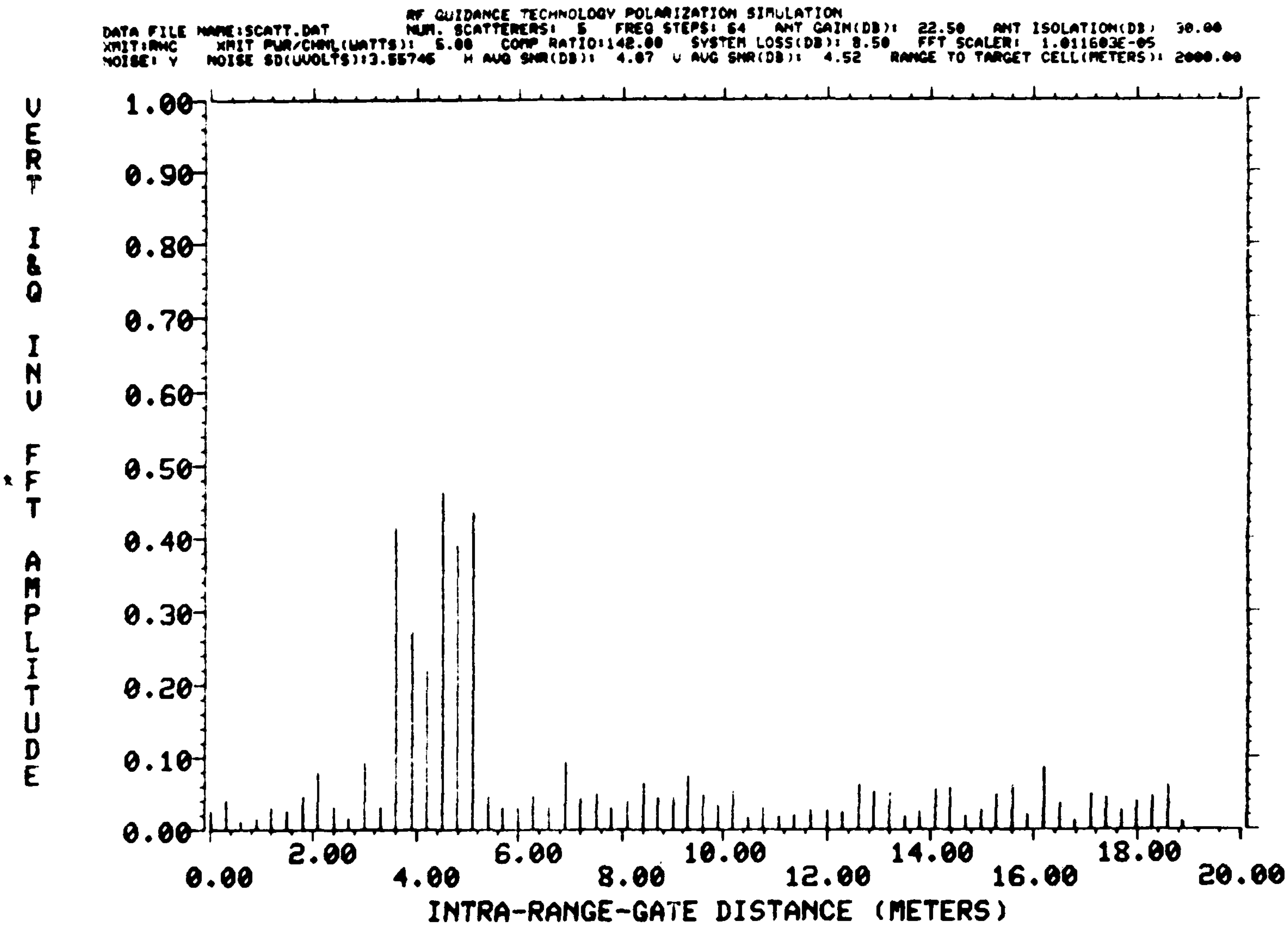


Figure 43. Inverse FFT of vertical I&Q for target model only.

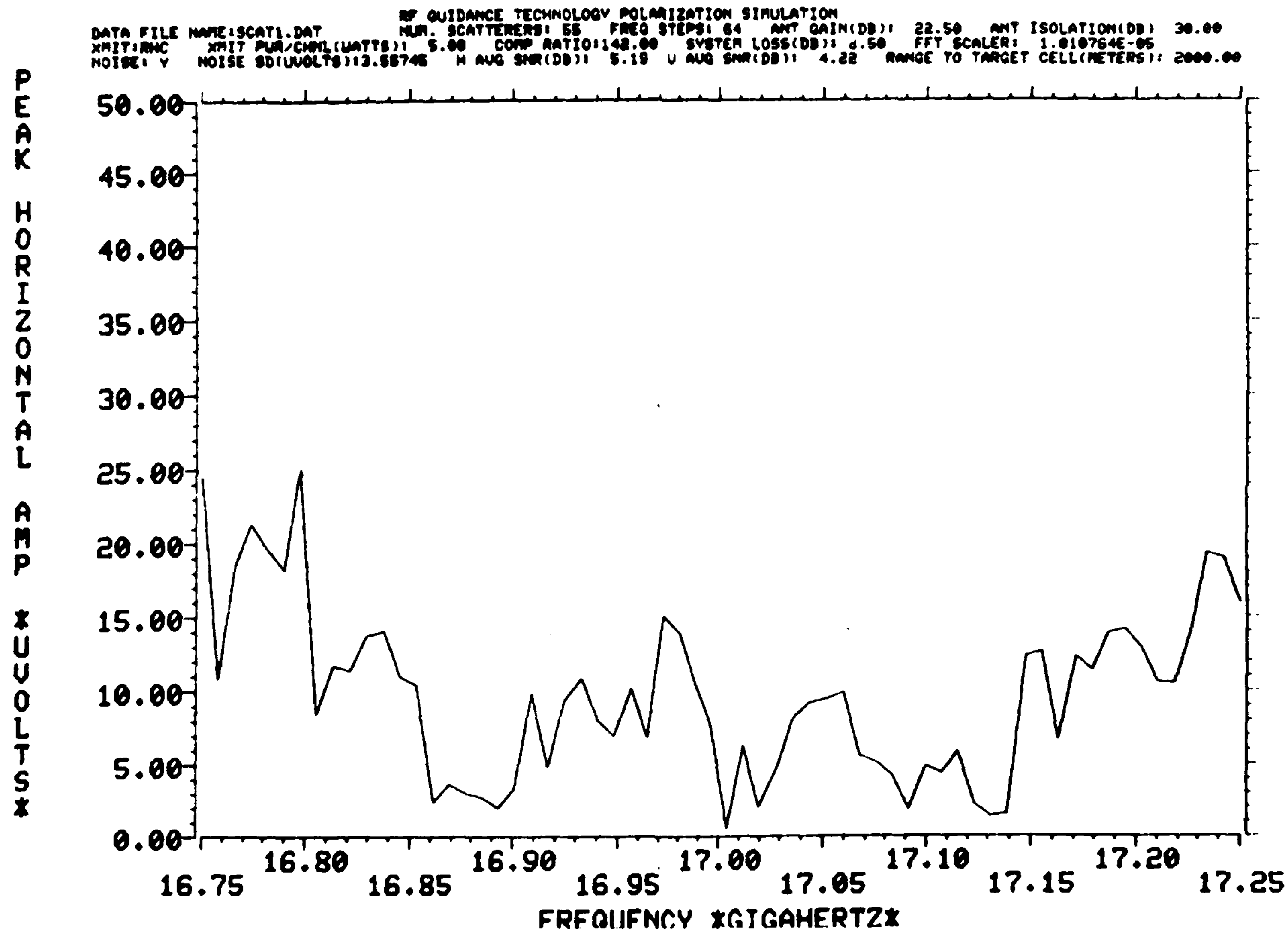


Figure 44. Peak horizontal voltage for signal to clutter ratio of +/ dB.

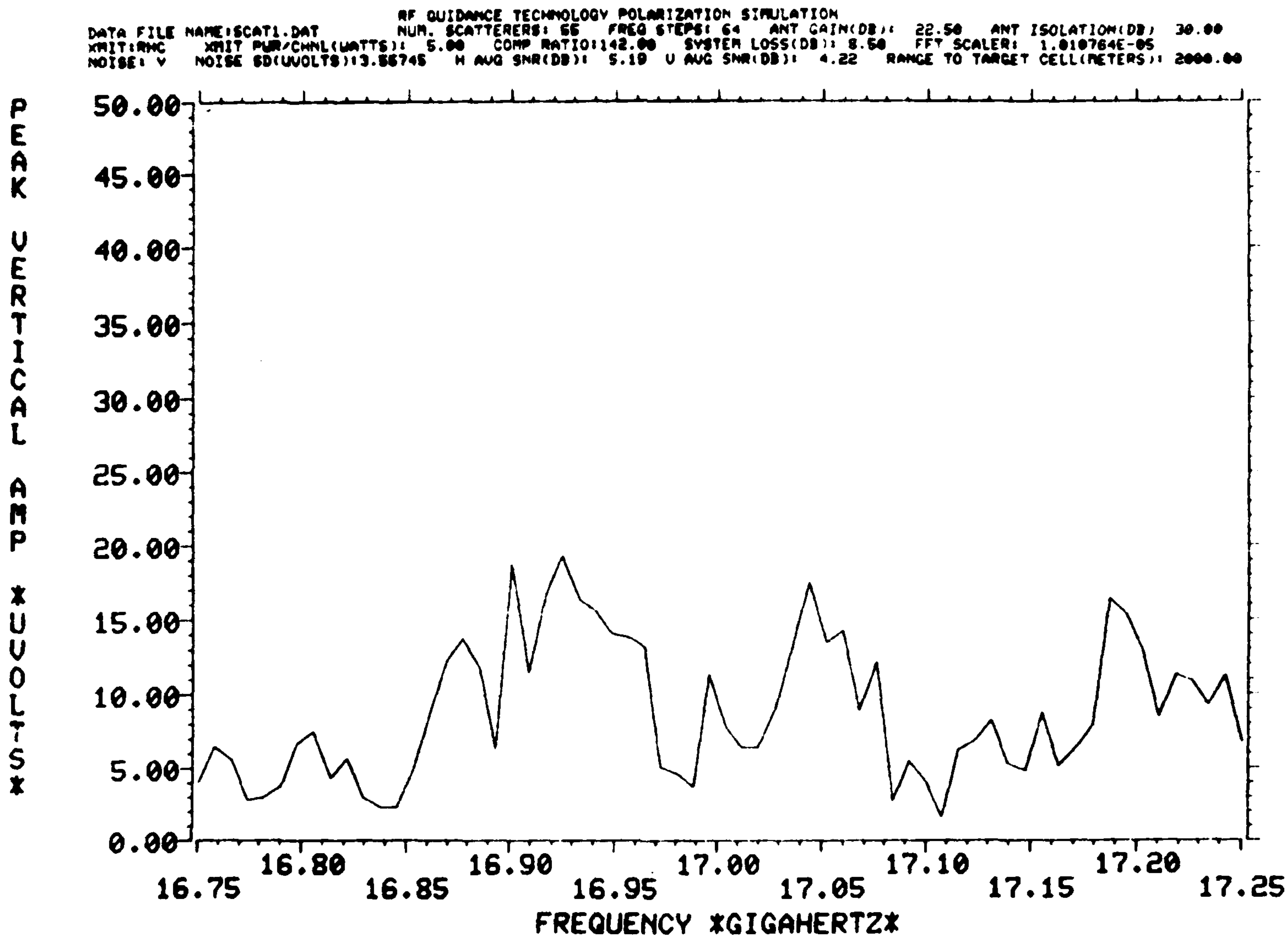


Figure 45. Peak vertical voltage for signal to clutter ratio of +7 dB.

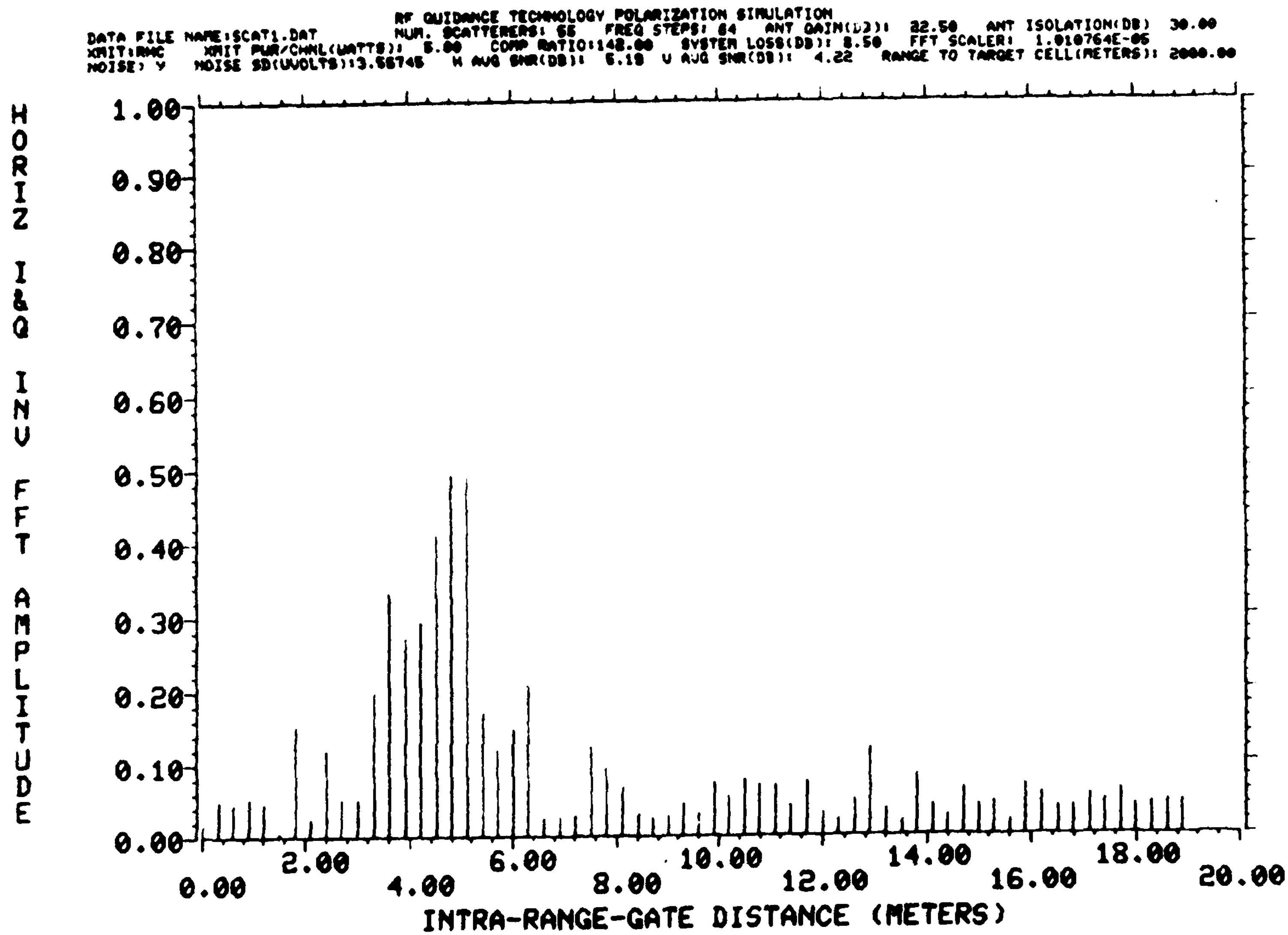


Figure 46. Inverse FFT of horizontal I&Q for signal to clutter ratio of +7 dB.

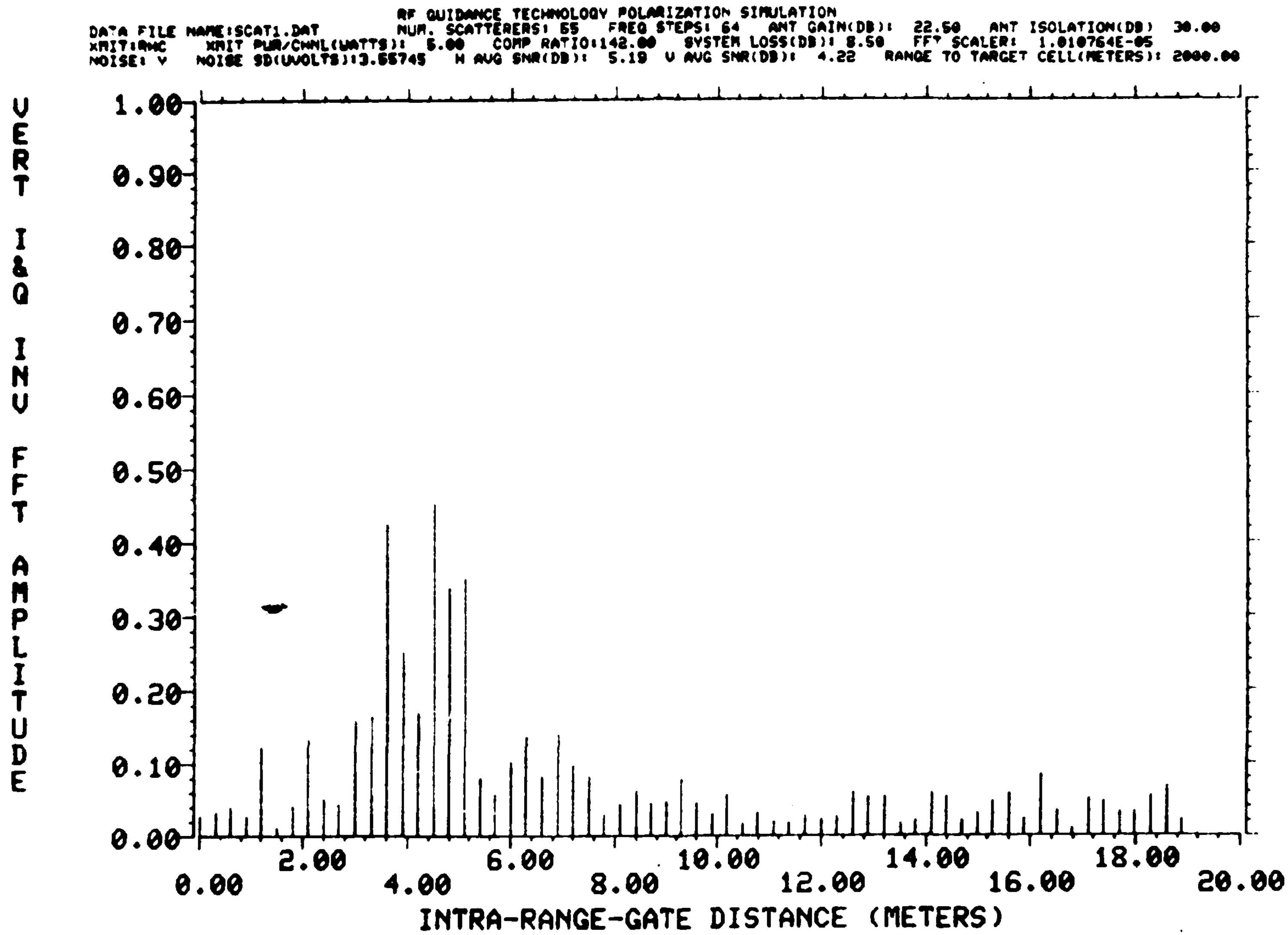


Figure 47. Inverse FFT of vertical I&Q for signal to clutter ratio of +7 dB.

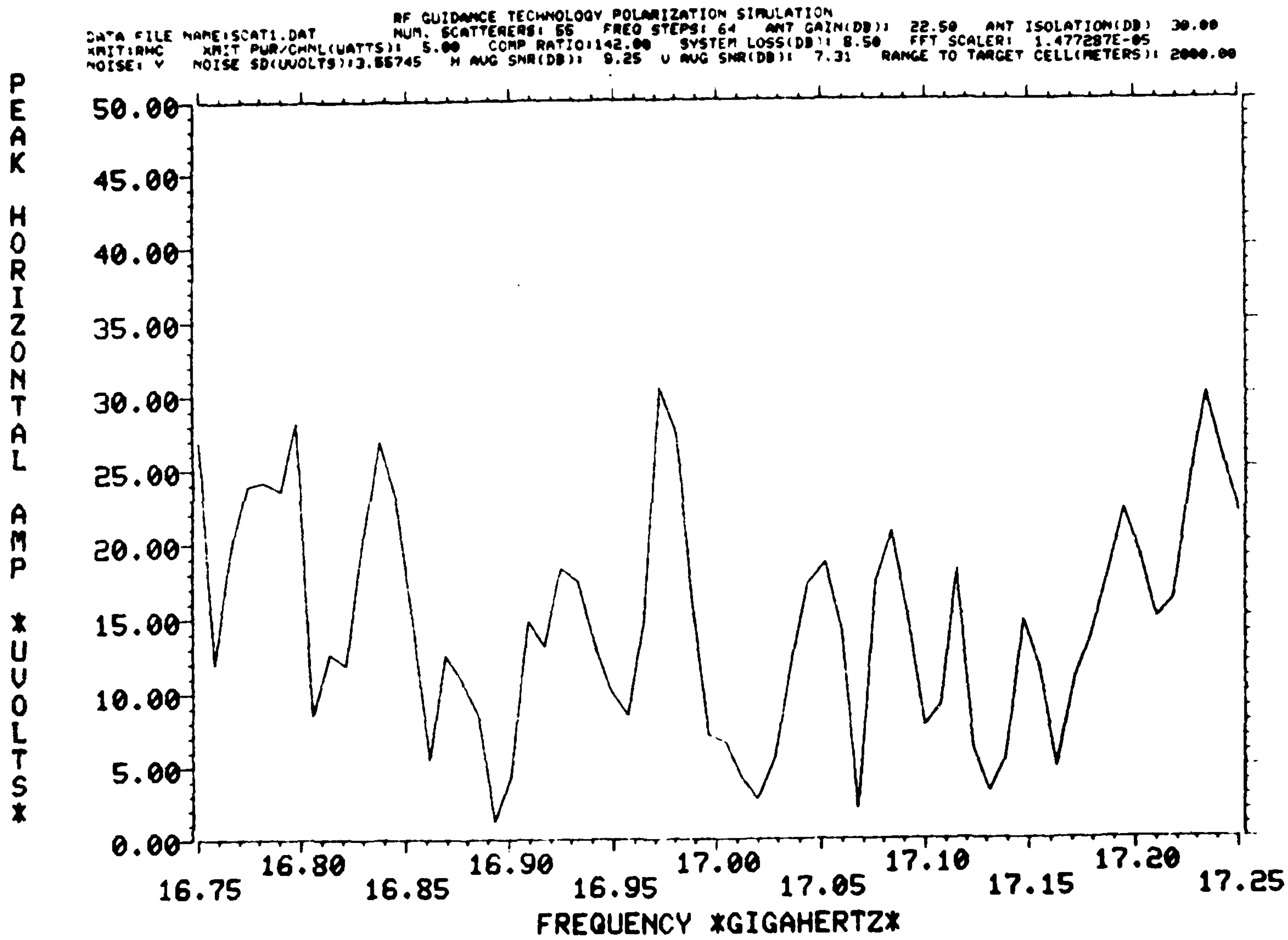


Figure 48. Peak horizontal voltage for signal to clutter ratio of -3 dB.

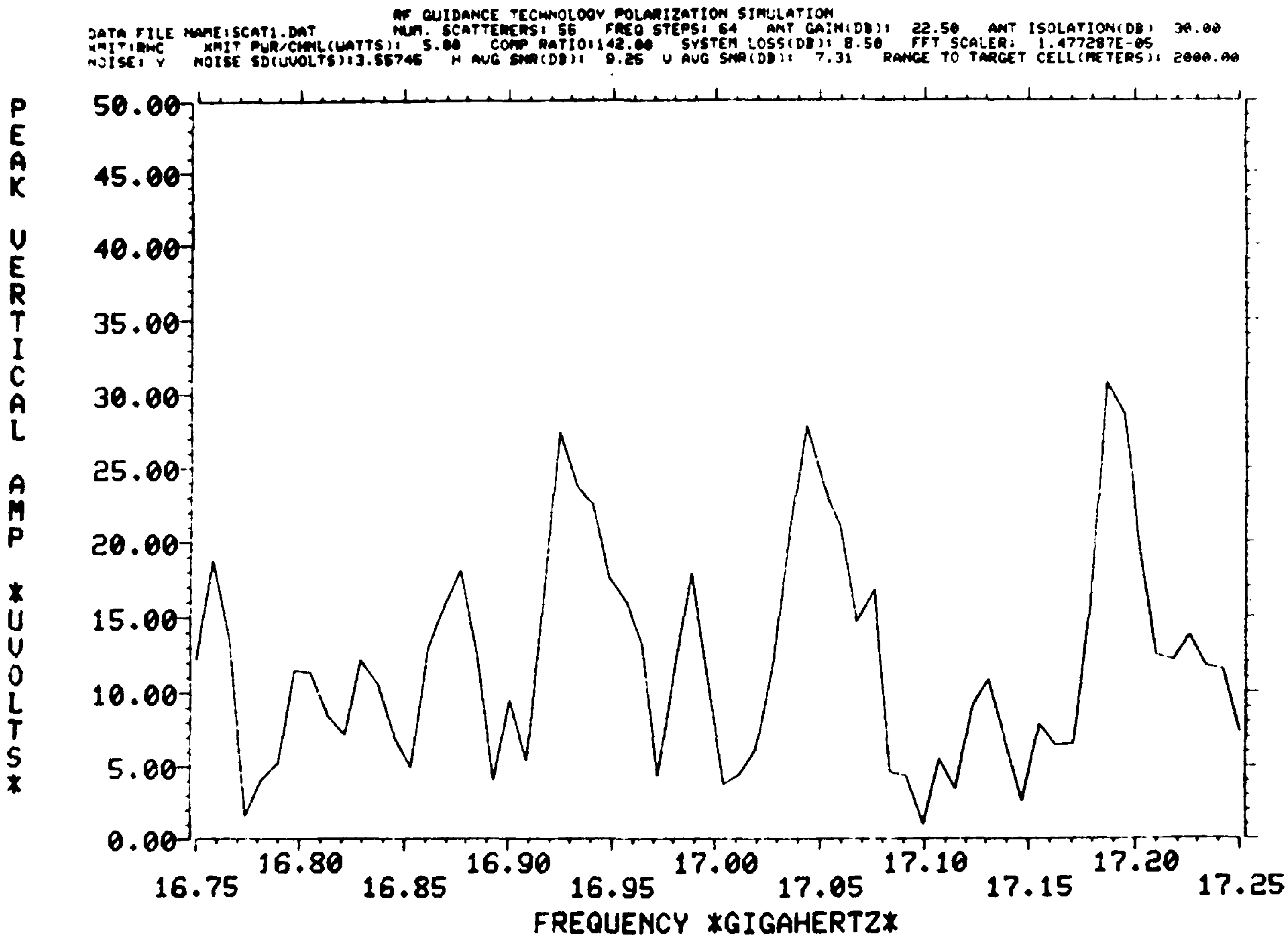


Figure 49. Peak vertical voltage for signal to clutter ratio of -3 dB.

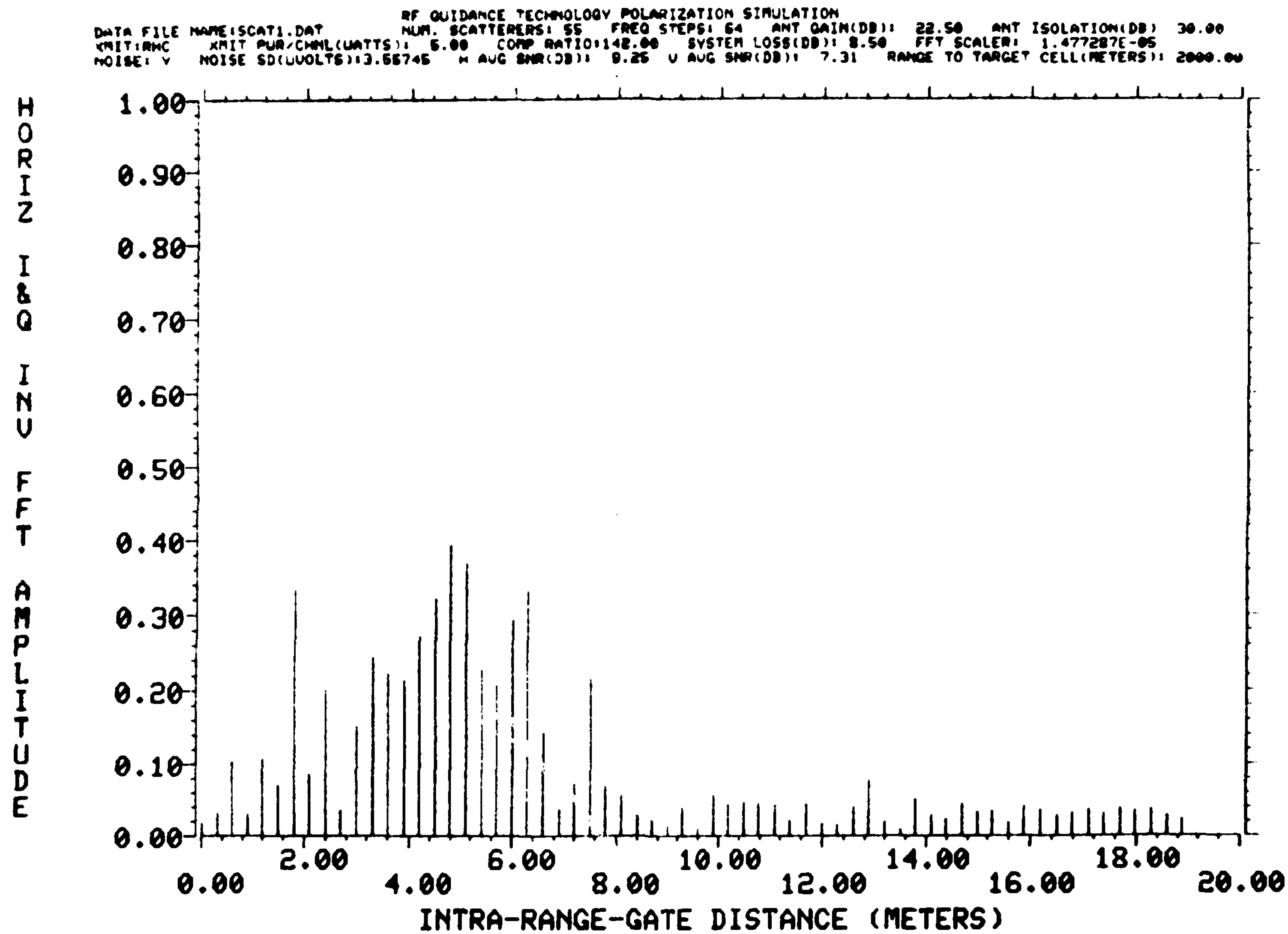


Figure 50. Inverse FFT of horizontal I&Q for signal to clutter ratio of -3 dB.

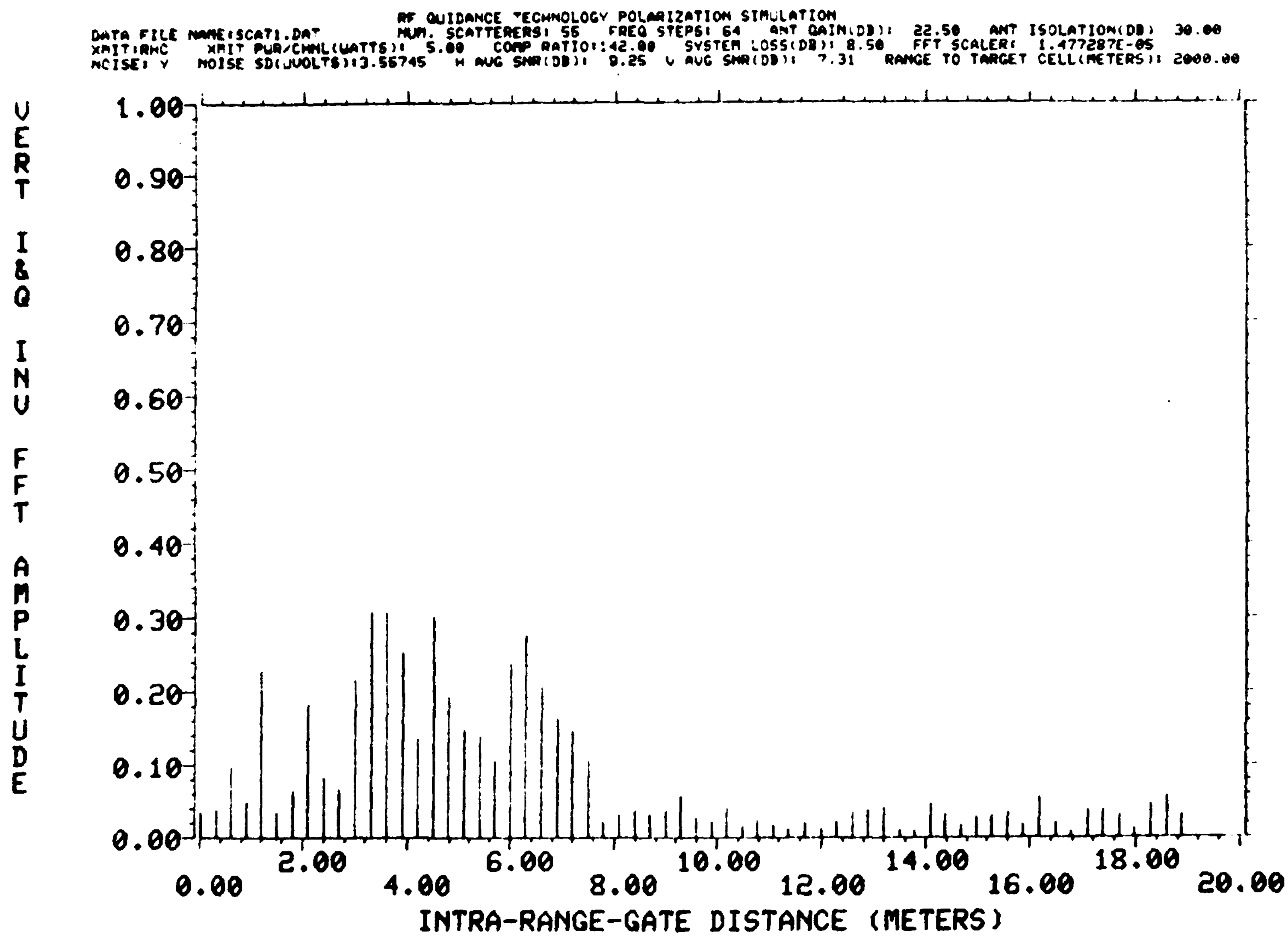


Figure 51. Inverse FFT of vertical I&Q for signal to clutter ratio of -3 dB.

APPENDIX

Simulation Flow Charts and Program Listing

The following flow charts were developed as an aid in following the mathematical development of signals. The program listing of subroutines is short enough to provide an easily followed path without flowcharts. This simulation has been developed and run on a Digital Equipment Corporation (DEC) 28K word PDP-11/10 computer running DEC's RT-11 operating system. The plots were performed utilizing a Tektronix terminal 4014 driven by in-house developed plotting software. The plotting subroutines are described by function only without software listing included in the program printout. This will provide a programming guide for tailoring plots to other systems.

DEC's RT-11 Subroutines

Call Assign - Attaches a disk file for reading or writing and assigns a logical unit number.

Call Close - Closes an attached disk file.

In-House Computer Subroutines

Call IAND - Performs logical bit anding of the two arguments.

Call SWR - Read computer switch register. Used to control line printer and hard copy functions.

Call NLOGN - Perform forward or inverse in place FFT of complex array.

In-House Plotting subroutines

Call PLOT - Erase 4014 screen.

Call V14CSZ - Select size of Alphanumeric characters typed on 4014.

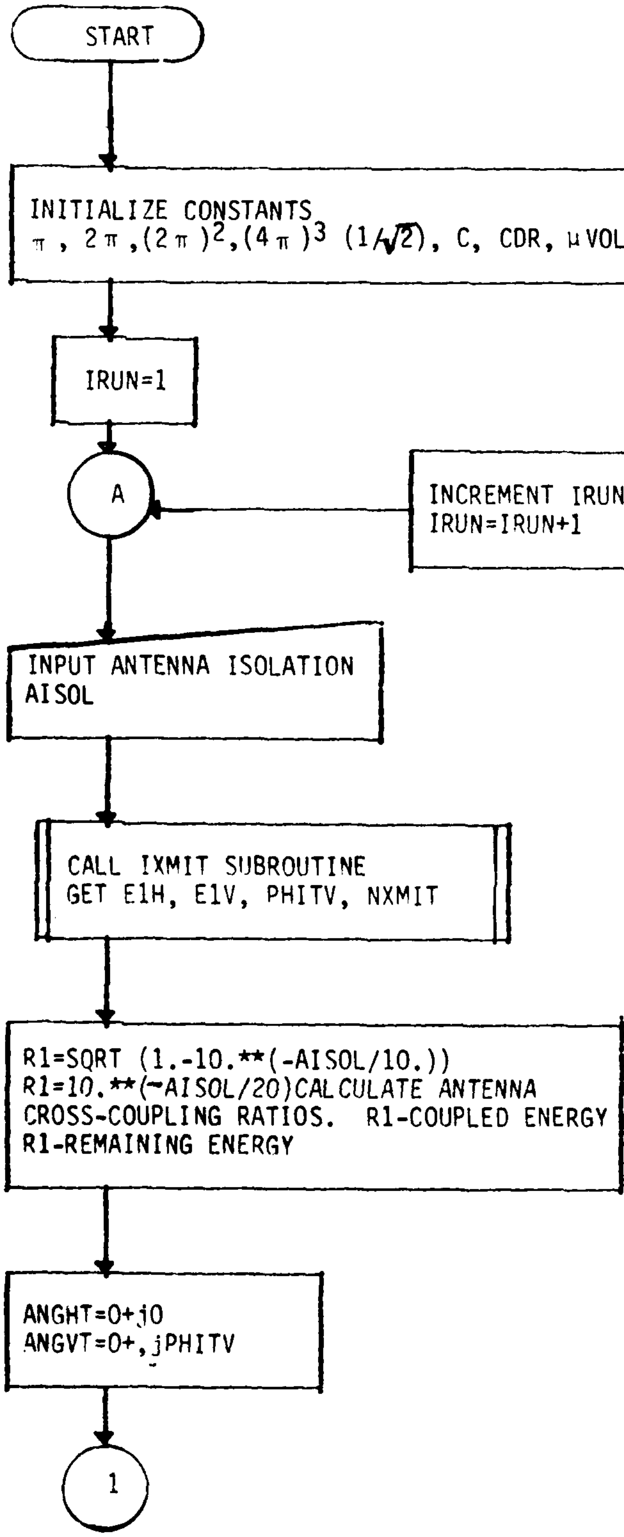
Call AXES - Draw plotting axes by screen position and tic-marks controlled by user units and store parameters for user units plotting by call LINE.

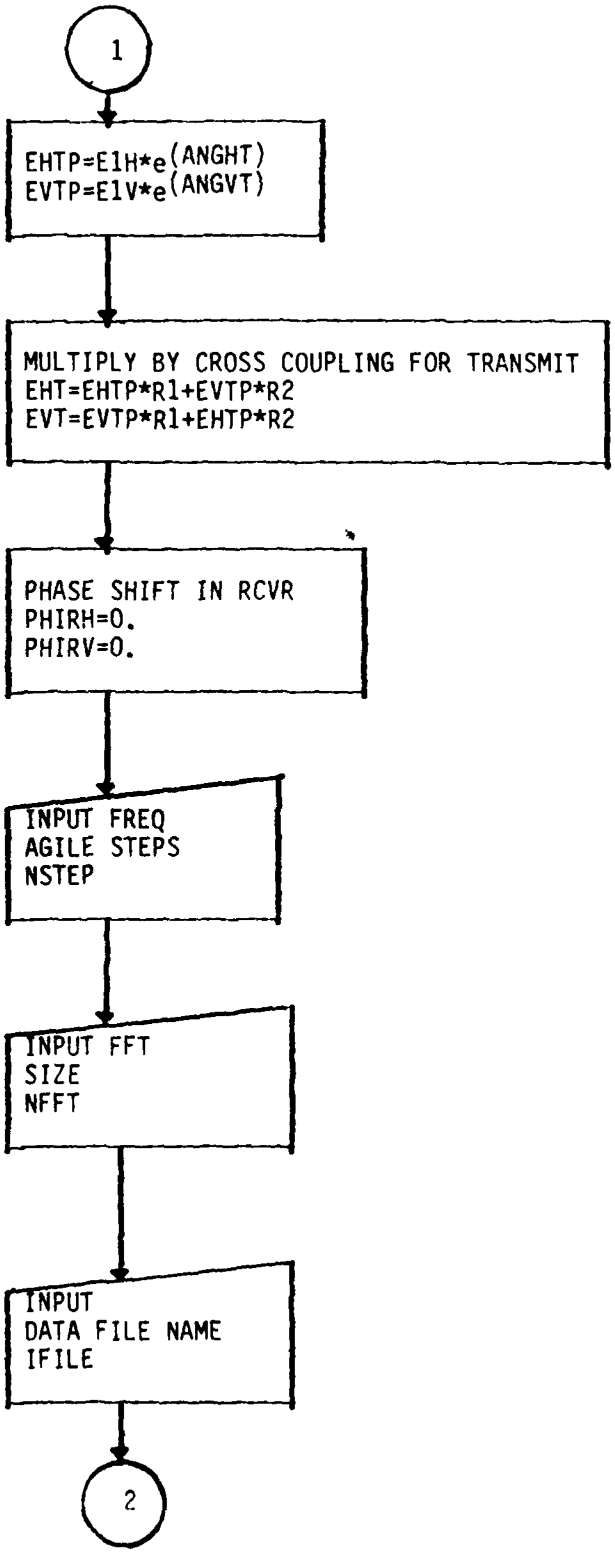
Call LINE - Draw graphic line on 4014 between two points described by user units.

Call HRDCPY - Cause hard copy of 4014 screen to be produced.

Call LABEL - Provide X and Y axes labels to be centered and typed on 4014.

Call STALL - Cause computer to wait momentarily for HRDCPY to be executed.


START
INITIALIZE CONSTANTS
π , 2π ,(2π)2,(4π)3 (1/√2), C, CDR, μVOLTS
IRUN=1
A
INCREMENT IRUN
IRUN=IRUN+1
INPUT ANTENNA ISOLATION
AISOL
B
CALL IXMIT SUBROUTINE
GET E1H, E1V, PHITV, NXMIT
R1=SQRT (1.-10.**(-AISOL/10.))
R1=10.**(-AISOL/20)CALCULATE ANTENNA
CROSS-COUPLING RATIOS. R1-COUPLED ENERGY
R1-REMAINING ENERGY
ANGHT=0+j0
ANGVT=0+,jPHITV
1


1
EHTP=E1H*e(ANGHT)
EVTP=E1V*e(ANGVT)
MULTIPLY BY CROSS COUPLING FOR TRANSMIT
EHT=EHTP*R1+EVTP*R2
EVT=EVTP*R1+EHTP*R2
PHASE SHIFT IN RCVR
PHIRH=0.
PHIRV=0.
INPUT FREQ
AGILE STEPS
NSTEP
INPUT FFT
SIZE
NFFT
INPUT
DATA FILE NAME
IFILE
2

2

READ DATA FILE
NOISE-ON OR OFF (1 or 0)
RIFBW-RECEIVER IF BANDWIDTH
RNFDB-RCVR NOISE FIGURE IN DB
CF-XMIT CENTER FREQ (HERTZ)
FBW-FREQ AGILE BANDWIDTH (HERTZ)
PRF-PULSE REP. FREQ (HERTZ)
PTPWR-XMIT POWER (WATTS)
CR-COMPRESSION RATIO
GAINA-ANTENNA GAIN (dB)
RANGE-RANGE TO LEADING EDGE OF RANGE CELL (METERS)
DBLOSS-SYSTEM LOSSES (dB)
ASCALE-AMPLITUDE PLOTTING AMPLITUDE SCALE (VOLTS)
NSCAT-NUMBER OF SCATTERERS

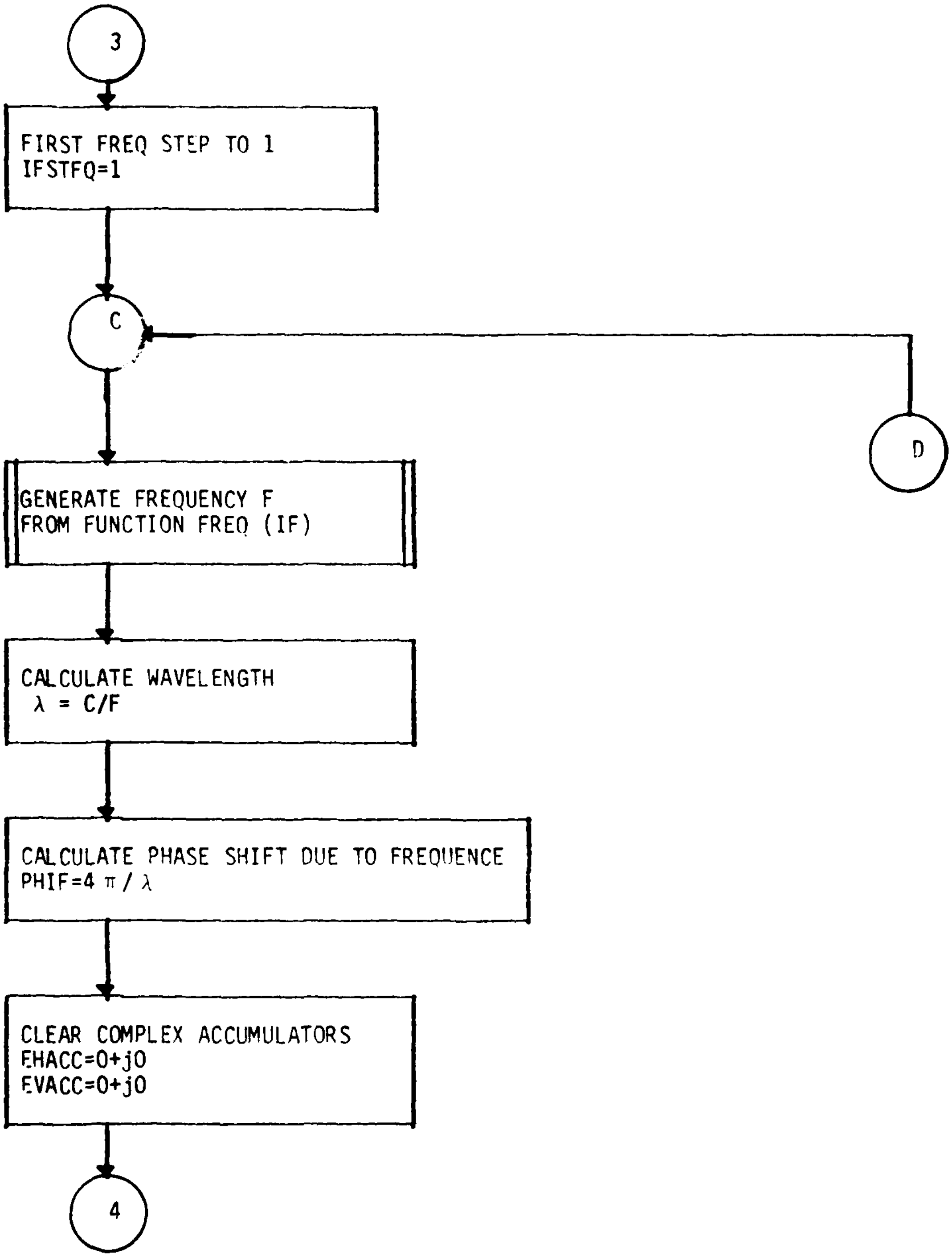
CALCULATE
DF=FBW/FLOAT(NSTEP-1)-FREQ STEP SIZE
ANTG=10.** (GAINA/10.)-ANTENNA GAIN
ANTG2=ANTG**2-ANTENNA GAIN SQUARED
RANGE4=RANGE**4.-RANGE TO THE FOURTH POWER
SLOSS=10.**(DBLOSS/10.)SYSTEM LOSSES IN EITHER H OR V CHANNEL
VARI=50.*1.38E-23*290.*RIFBW*RNF

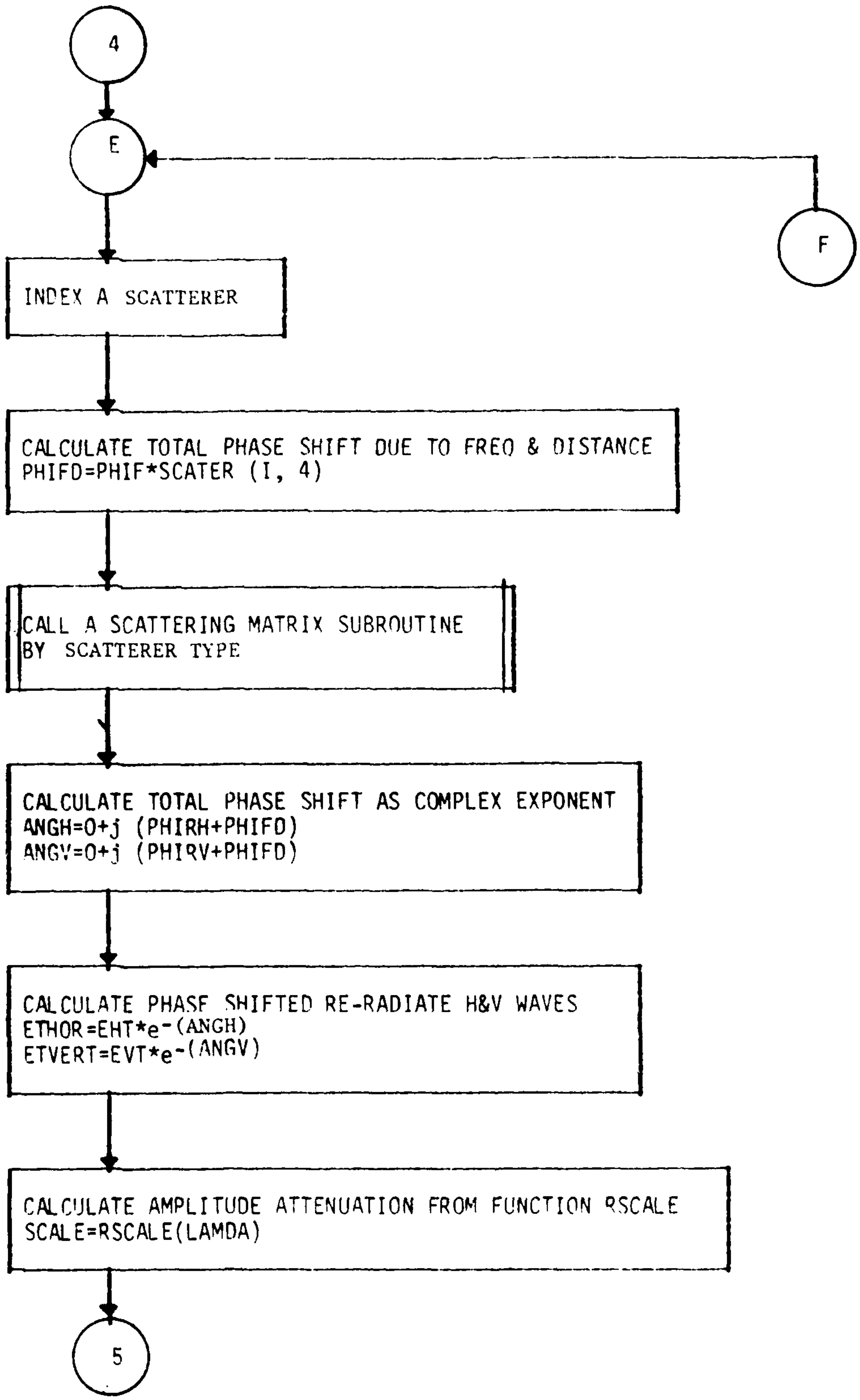
READ SCATTERERS' DATA
TYPE, SIZE, ROTATION ANGLE, DISTANCE

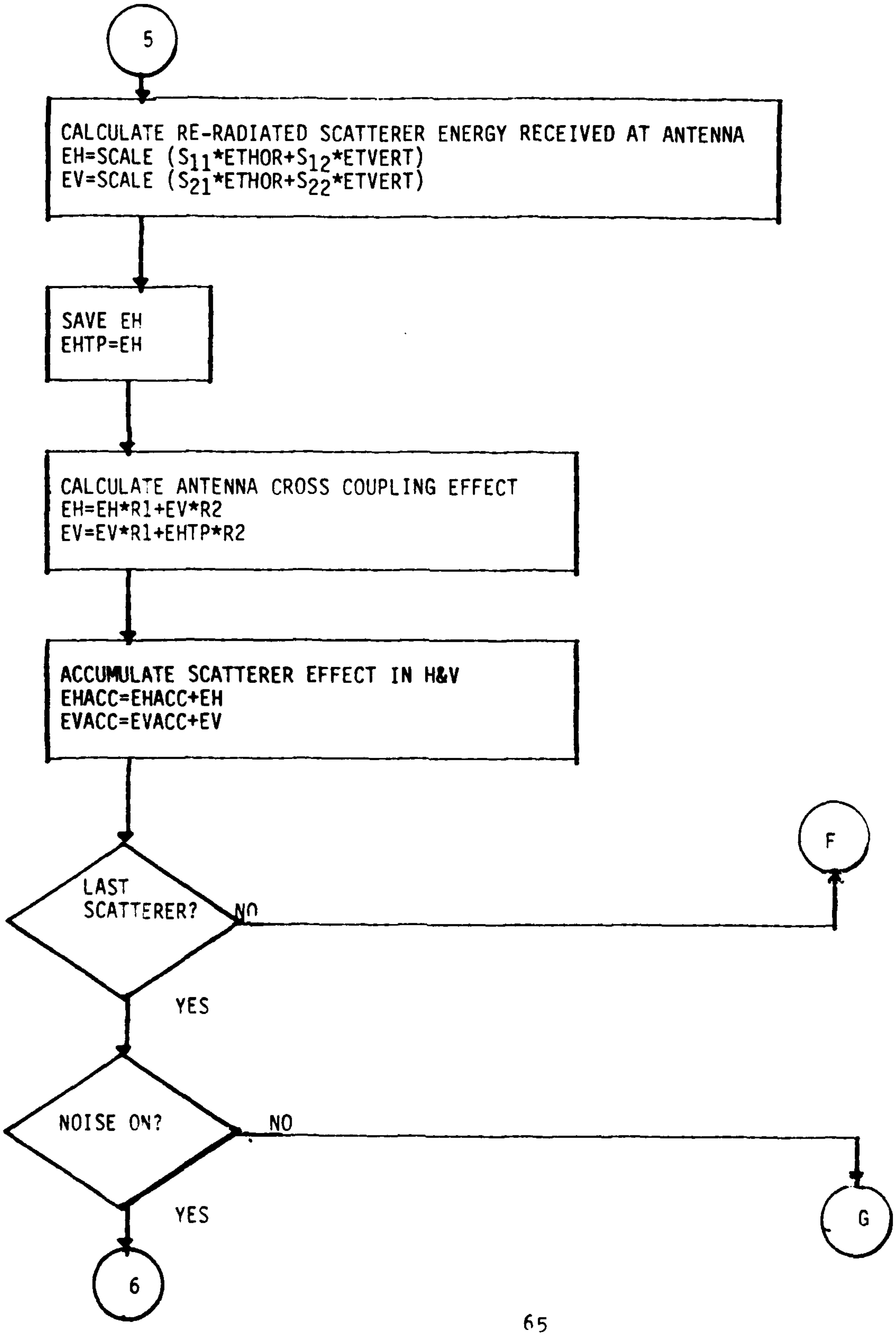
CONVERT ROTATION ANGLES FROM DEGREES TO RADANS

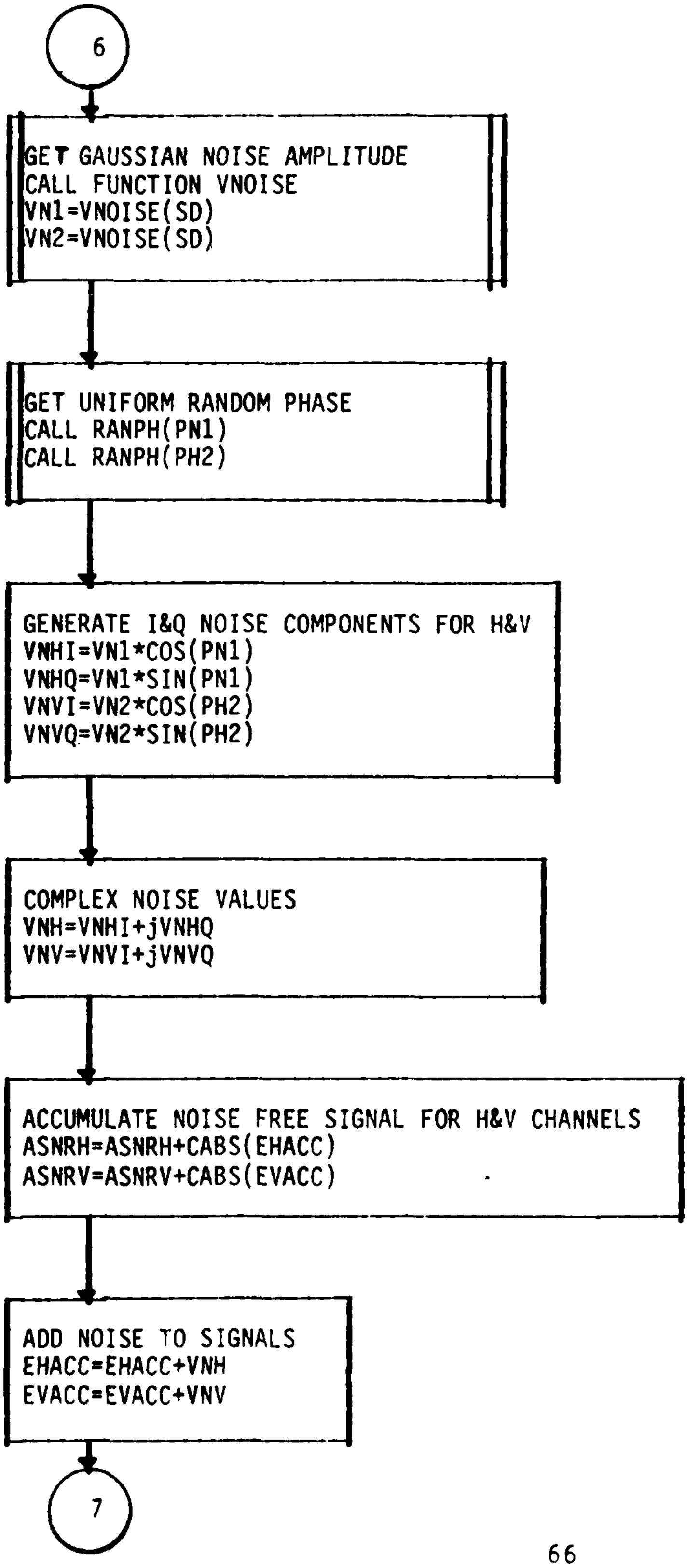
SET NOISE FREQ ACCUMULATORS TO
ASHRH=0
ASNRV=0

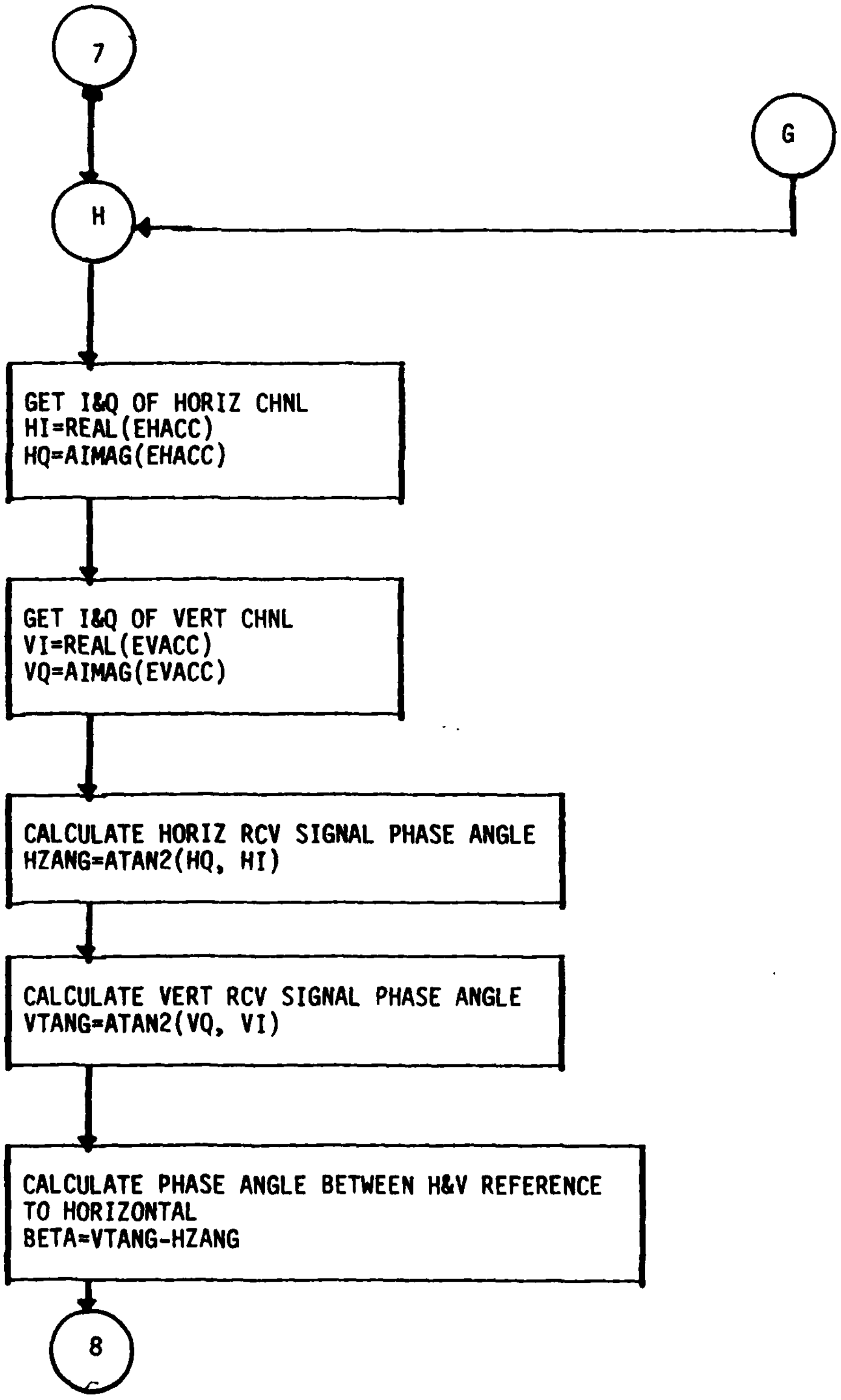
3

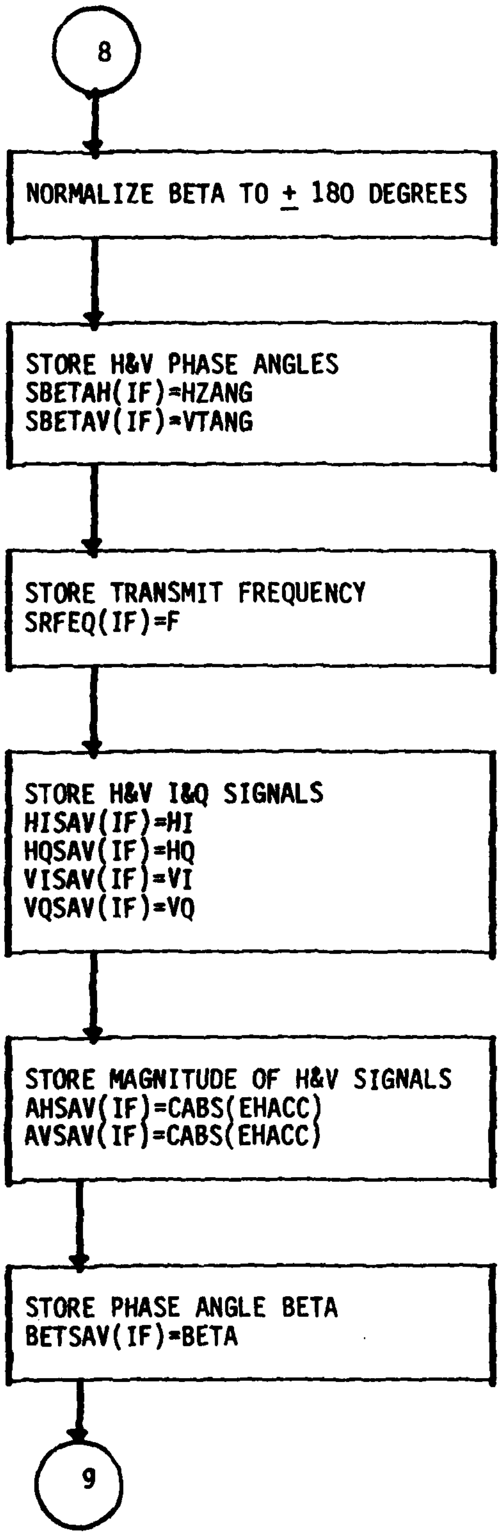

3
FIRST FREQ STEP TO 1
IFSTFQ=1
C
D
GENERATE FREQUENCY F
FROM FUNCTION FREQ (IF)
CALCULATE WAVELENGTH
λ = C/F
CALCULATE PHASE SHIFT DUE TO FREQUENCE
PHIF=4 π / λ
CLEAR COMPLEX ACCUMULATORS
EHACC=0+j0
EVACC=0+j0
4

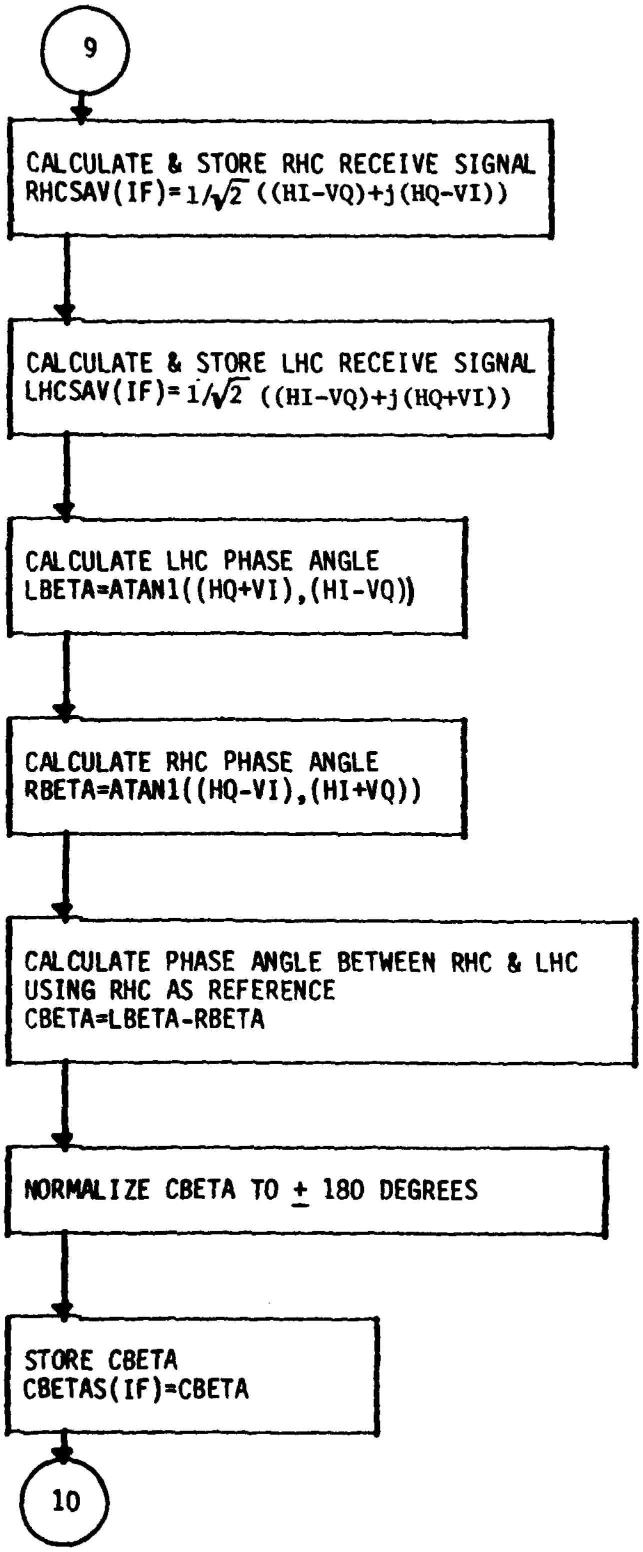

4
E
F
INDEX A SCATTERER
CALCULATE TOTAL PHASE SHIFT DUE TO FREQ & DISTANCE
PHIFD=PHIF*SCATER (I, 4)
CALL A SCATTERING MATRIX SUBROUTINE
BY SCATTERER TYPE
CALCULATE TOTAL PHASE SHIFT AS COMPLEX EXPONENT
ANGH=0+j (PHIRH+PHIFD)
ANGV=0+j (PHIRV+PHIFD)
CALCULATE PHASE SHIFTED RE-RADIATE H&V WAVES
ETHOR=EHT*e-(ANGH)
ETVERT=EVT*e-(ANGV)
CALCULATE AMPLITUDE ATTENUATION FROM FUNCTION RSCALE
SCALE=RSCALE(LAMDA)
5

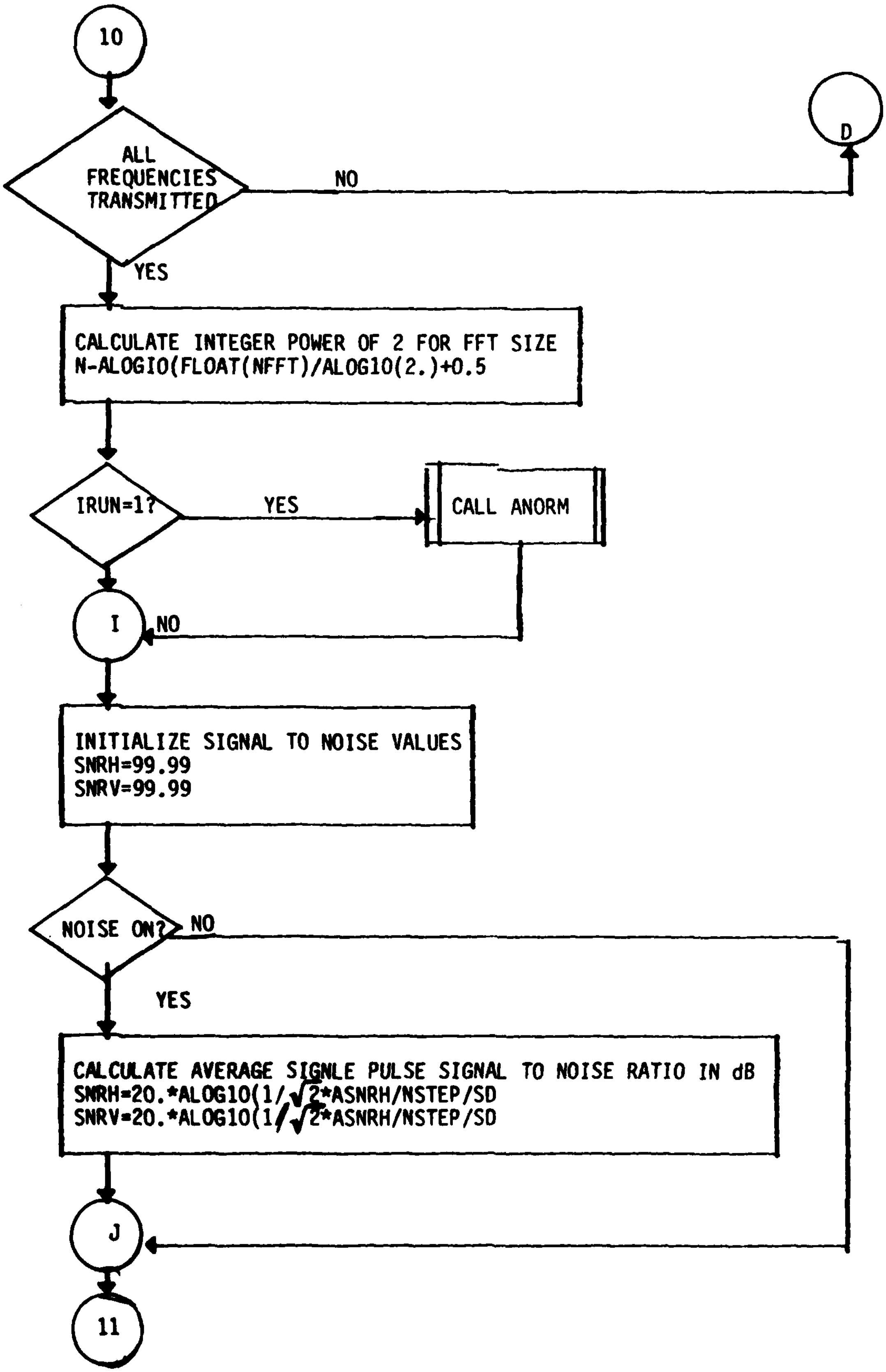

5
CALCULATE RE-RADIATED SCATTERER ENERGY RECEIVED AT ANTENNA
EH=SCALE (S_{11}*ETHOR+S_{12}*ETVERT)
EV=SCALE (S_{21}*ETHOR+S_{22}*ETVERT)
SAVE EH
EHTP=EH
CALCULATE ANTENNA CROSS COUPLING EFFECT
EH=EH*R1+EV*R2
EV=EV*R1+EHTP*R2
ACCUMULATE SCATTERER EFFECT IN H&V
EHACC=EHACC+EH
EVACC=EVACC+EV
LAST SCATTERER?
NO
F
YES
NOISE ON?
NO
YES
6
G

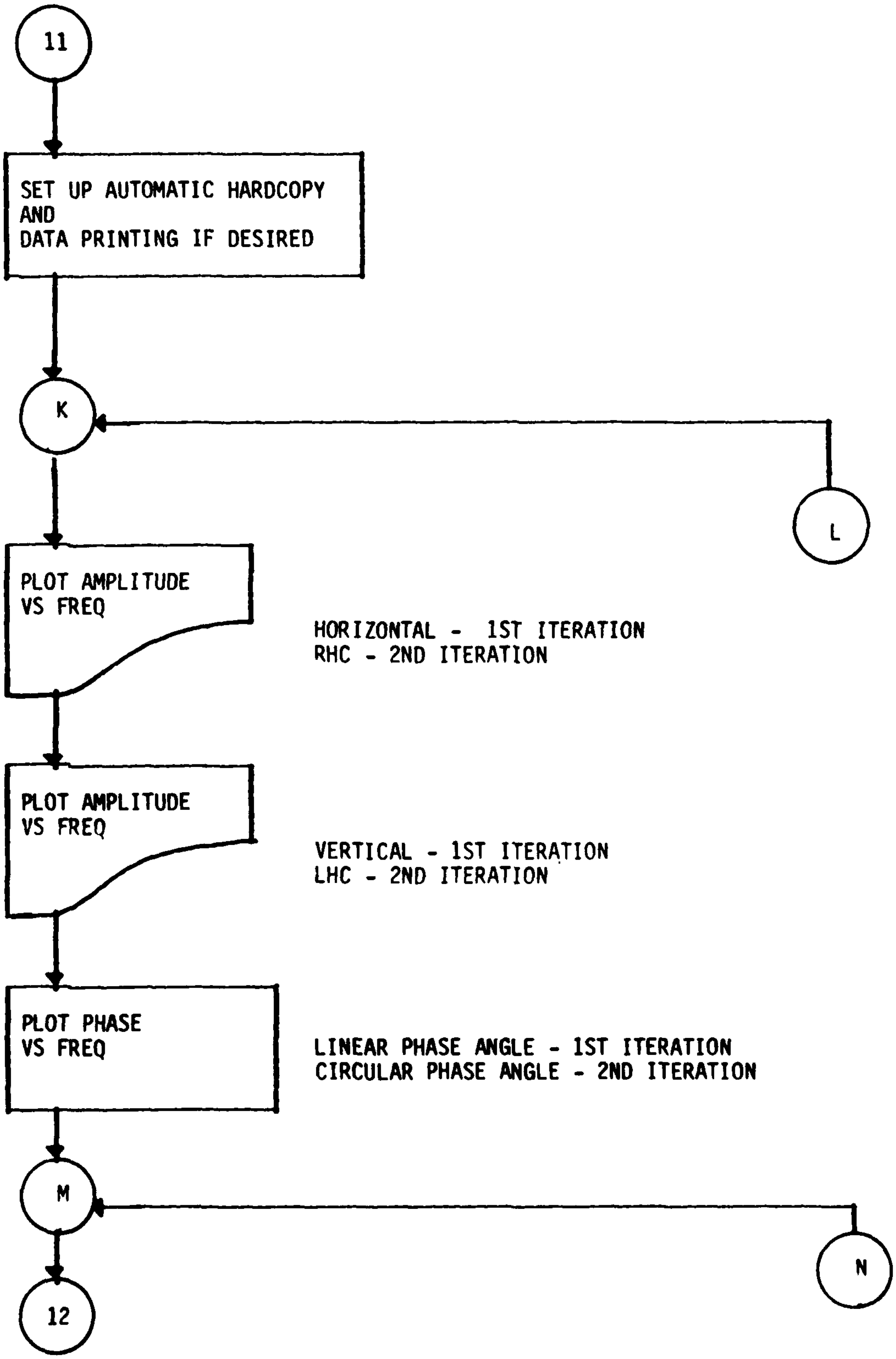

6
GET GAUSSIAN NOISE AMPLITUDE
CALL FUNCTION VNOISE
VN1=VNOISE(SD)
VN2=VNOISE(SD)
GET UNIFORM RANDOM PHASE
CALL RANPH(PN1)
CALL RANPH(PH2)
GENERATE I&Q NOISE COMPONENTS FOR H&V
VNHI=VN1*COS(PN1)
VNHQ=VN1*SIN(PN1)
VNVI=VN2*COS(PH2)
VNVQ=VN2*SIN(PH2)
COMPLEX NOISE VALUES
VNH=VNHI+jVNHQ
VNV=VNVI+jVNVQ
ACCUMULATE NOISE FREE SIGNAL FOR H&V CHANNELS
ASNRH=ASNRH+CABS(EHACC)
ASNRV=ASNRV+CABS(EVACC)
ADD NOISE TO SIGNALS
EHACC=EHACC+VNH
EVACC=EVACC+VNV
7

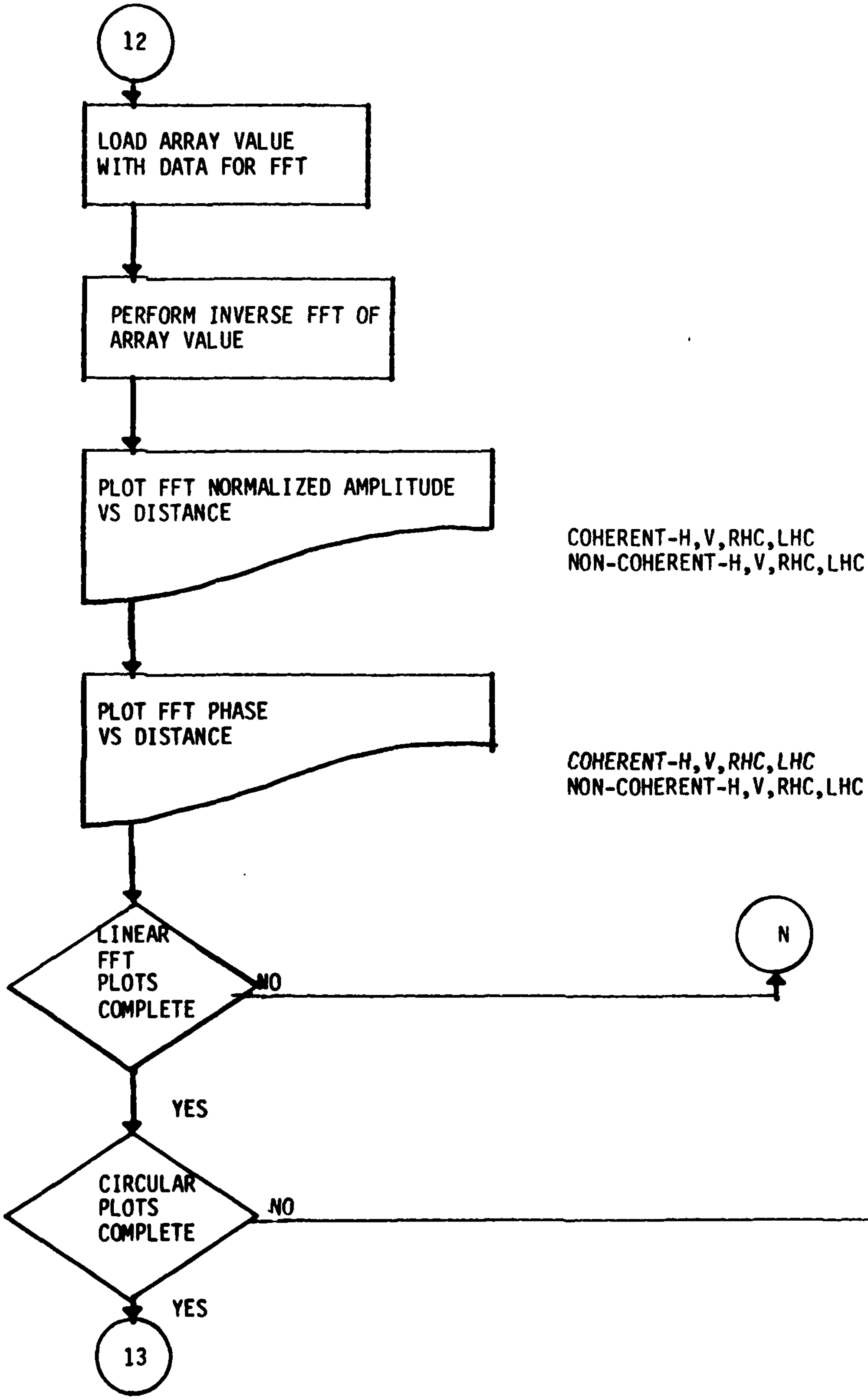

7
G
H
GET I&Q OF HORIZ CHNL
HI=REAL(EHACC)
HQ=AIMAG(EHACC)
GET I&Q OF VERT CHNL
VI=REAL(EVACC)
VQ=AIMAG(EVACC)
CALCULATE HORIZ RCV SIGNAL PHASE ANGLE
HZANG=ATAN2(HQ, HI)
CALCULATE VERT RCV SIGNAL PHASE ANGLE
VTANG=ATAN2(VQ, VI)
CALCULATE PHASE ANGLE BETWEEN H&V REFERENCE
TO HORIZONTAL
BETA=VTANG-HZANG
8


8
NORMALIZE BETA TO ± 180 DEGREES
STORE H&V PHASE ANGLES
SBETAH(IF)=HZANG
SBETAV(IF)=VTANG
STORE TRANSMIT FREQUENCY
SRFEQ(IF)=F
STORE H&V I&Q SIGNALS
HISAV(IF)=HI
HQSAV(IF)=HQ
VISAV(IF)=VI
VQSAV(IF)=VQ
STORE MAGNITUDE OF H&V SIGNALS
AHSAV(IF)=CABS(EHACC)
AVSAV(IF)=CABS(EHACC)
STORE PHASE ANGLE BETA
BETSAV(IF)=BETA
9

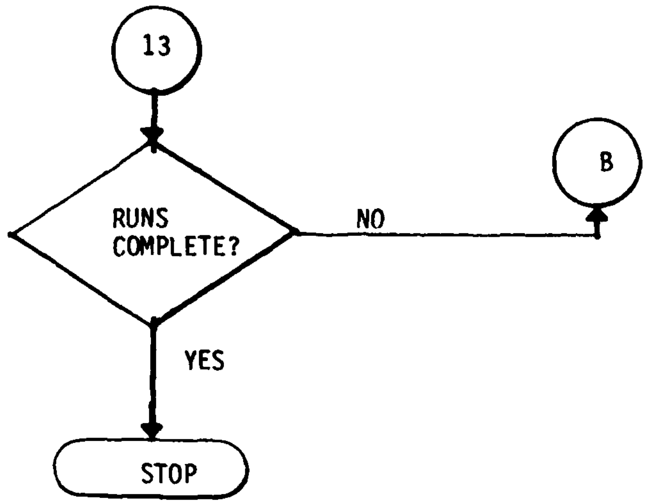

9
CALCULATE & STORE RHC RECEIVE SIGNAL
RHCSAV(IF)= 1/√2 ((HI-VQ)+j(HQ-VI))
CALCULATE & STORE LHC RECEIVE SIGNAL
LHCSAV(IF)= 1/√2 ((HI-VQ)+j(HQ+VI))
CALCULATE LHC PHASE ANGLE
LBETA=ATAN1((HQ+VI),(HI-VQ))
CALCULATE RHC PHASE ANGLE
RBETA=ATAN1((HQ-VI),(HI+VQ))
CALCULATE PHASE ANGLE BETWEEN RHC & LHC
USING RHC AS REFERENCE
CBETA=LBETA-RBETA
NORMALIZE CBETA TO ± 180 DEGREES
STORE CBETA
CBETAS(IF)=CBETA
10


10
ALL FREQUENCIES TRANSMITTED
NO
D
YES
CALCULATE INTEGER POWER OF 2 FOR FFT SIZE
N-ALOGIO(FLOAT(NFFT)/ALOG10(2.)+0.5
IRUN=1?
YES
CALL ANORM
I
NO
INITIALIZE SIGNAL TO NOISE VALUES
SNRH=99.99
SNRV=99.99
NOISE ON?
NO
YES
CALCULATE AVERAGE SIGNLE PULSE SIGNAL TO NOISE RATIO IN dB
SNRH=20.*ALOG10(1/√2*ASNRH/NSTEP/SD
SNRV=20.*ALOG10(1/√2*ASNRH/NSTEP/SD
J
11


11
SET UP AUTOMATIC HARDCOPY
AND
DATA PRINTING IF DESIRED
K
L
PLOT AMPLITUDE
VS FREQ
HORIZONTAL - 1ST ITERATION
RHC - 2ND ITERATION
PLOT AMPLITUDE
VS FREQ
VERTICAL - 1ST ITERATION
LHC - 2ND ITERATION
PLOT PHASE
VS FREQ
LINEAR PHASE ANGLE - 1ST ITERATION
CIRCULAR PHASE ANGLE - 2ND ITERATION
M
N
12



12
LOAD ARRAY VALUE WITH DATA FOR FFT
PERFORM INVERSE FFT OF ARRAY VALUE
PLOT FFT NORMALIZED AMPLITUDE VS DISTANCE
COHERENT-H,V,RHC,LHC
NON-COHERENT-H,V,RHC,LHC
PLOT FFT PHASE VS DISTANCE
COHERENT-H,V,RHC,LHC
NON-COHERENT-H,V,RHC,LHC
LINEAR FFT PLOTS COMPLETE
NO
N
YES
CIRCULAR PLOTS COMPLETE
NO
L
YES
13


13
RUNS COMPLETE?
NO
B
YES
STOP

```
0001          PROGRAM SIMPTS
        C
        C    PROGRAM TO SIMULATE THE RF GUIDANCE TECHNOLOGY'S POLARIMETRIC
        C       TECHNOLOGY SEEKER (PTS).
        C
        C       WRITTEN BY: F. W. SEDENQUIST AND R. F. RUSSELL  4-FEB-82
        C
        C       LATEST UPDATE: 28-OCT-82
        C
0002          INTEGER NXAXIS(20),NYAXIS(20)
0003          INTEGER IFILE(8),NXMIT(2)
0004          REAL LBETA,LAMDA
0005          COMPLEX VALUE(256)
0006          COMPLEX AVGVAL
0007          DIMENSION SFREQ(256)
0008          DIMENSION SBETAH(256),SBETAV(256)
0009          DIMENSION SCATER(100,4),AHSAV(256),AVSAV(256),BETSAV(256)
0010          DIMENSION HQSAV(256),HISAV(256),VQSAV(256),VISAV(256)
0011          DIMENSION CBETAS(256)
0012          DIMENSION A(20)
0013          COMPLEX RHCSAV(256),LHCSAV(256)
0014          COMPLEX SMATRX(2,2),EH,EV,ETHOR,ETVERT,ANGH,ANGV,EHTP,EVTP,EHT,EVT
0015          COMPLEX ANGHT,ANGVT
0016          COMPLEX EHACC,EVACC,VNH,VNV
0017          COMMON /WORKF/IFSTFQ,IUP,LSTEP,NSTEP,DF,CF,FBW
0018          COMMON /WKSCT/ SCATER,SMATRX
0019          COMMON /HEAD/AISOL,NSCAT,GAINA,NOISE,
            1    RANGE,DBLOSS,NXMIT,IFILE,SD,BIG,
            1    SNRH,SNRV,SNRHI,SNRHQ,SNRVI,SNRVQ,SNR
0020          COMMON /WORK/HQSAV,HISAV,VQSAV,VISAV,SFREQ,SBETAH,SBETAV,BETSAV,
            1              RHCSAV,LHCSAV,CBETAS,AHSAV,AVSAV,
            1              VALUE
0021          COMMON /SIGNAL/PTPAR,RANGE4,CR,ANTG2,SLOSS,PI4C
        C
        C   INITIALIZATION VALUES
0022          VIDSR2=1./SQRT(2.)
0023          UVOLTS=1.E-6          !MICRO-VOLTS SCALER
0024          C=2.99793E8
0025          ICPY=0
0026          IRUN=1
0027          PI=3.14159
0028          PI2=2.*PI
0029          PI4=2.*PI2
0030          PI4C=PI4**3.
0031          CON=PI/180. !CONVERT DEGREES TO RADIANS
        C
0032          CALL PLOT(0)
0033          CALL V14CS2(1)
0034          TYPE 6005
0035          ACCEPT 6004,AISOL
0036          CALL XMIT(EIH,EIV,PHITV,NXMIT)
0037          R1=SQRT(1.-10.**(-AISOL/10.))         !REMAINING VOLTAGE RATIO
0038          R2=10.**(-AISOL/20.)          !TRANSFERED VOLTAGE RATIO
        C       HORIZ TRANSMIT POWER
```

```
0039          ANGHT=CMPLX(0.,0.)
0040          ANGVT=CMPLX(0.,PHITV)
0041          EHTP=E1H*CEXP(ANGHT)
0042          EVTP=E1V*CEXP(ANGVT)
      C       HORIZONTAL TRANSMIT COMPONENT WITH ANTENNA X-COUPLING
0043          EHT=EHTP*R1+EVTP*R2
      C       VERTICAL TRANSMIT COMPONENT WITH ANTENNA X-COUPLING
0044          EVT=EVTP*R1+EHTP*R2
0045          PHIRH=0.     !PHASE SHIFT TO RECEIVED HOR SIG
0046          PHIRV=0.     !PHASE SHIFT TO RECEIVED VERT SIG
0047          TYPE 6003
0048          ACCEPT 6002,NSTEP
0049          TYPE 6001
0050          ACCEPT 6002,NFFT
0051    11111 CALL PLOT(0)
0052          TYPE 6000,IRUN
      C
      C   *** ALL INPUT DATA IS READ FROM FILE INPUT TO IFILE
      C
0053          ACCEPT 6012,IFILE
0054          CALL ASSIGN (22,IFILE,0,'RDO')
0055          READ(22,6002)NOISE           !ENTER 0 FOR NOISE OFF, 1 FOR NOISE ON
0056          READ(22,6004)RIFBW  !RECEIVER IF BANDWIDTH IN HERTZ
0057          READ(22,6004)RNFDB           !RECEIVER NOISE FIGURE IN DB
0058          RNF=10.**(RNFDB/20.)         !RECEIVER NOISE FIGURE
      C   VARIANCE = RKTBNF
0059          VARI=(50.*1.38E-23*290.*RIFBW*RNF)  !50 OHM IMPEDANCE
0060          SD=SQRT(VARI)        !STANDARD DEVIATION = SQRT(VARIANCE)
0061          READ(22,6004)CF              !TRANSMITTER CENTER FREQUENCY
0062          READ(22,6004)FBW             !FREQUENCY AGILITY BANDWIDTH
0063          READ(22,6004)PRF             !TRANSMIT PULSE REP FREQ
0064          DF=FBW/FLOAT(NSTEP-1)
0065          READ(22,6004)PTPWR  !AVERAGE XMIT PWR HORIZ OR VERT CHANNEL
      C        WHEN XMITTER TURNED ON (I.E. XMIT POWER/2)
0066          READ(22,6004)CR              !COMPRESSION RATIO
0067          READ(22,6004)GAINA  !ANTENNA GAIN IN DB
0068          ANTG=10.**(GAINA/10.)        !ANTENNA GAIN
0069          ANTG2=ANTG**2.
0070          READ(22,6004)RANGE  !RANGE IN METERS TO CELL OF INTEREST
0071          RANGE4=RANGE**4.
0072          READ(22,6004)DBLOSS !SYSTEM LOSSES IN DB FOR EITHER H OR V CHANNEL
0073          SLOSS=10.**(DBLOSS/10.)      !SYSTEM LOSSES EITHER CHANNEL H OR V
0074          READ (22,6004)ASCALE         !AMPLITUDE SCALE MAX SCALE
      C
      C       THE NEXT LINE MUST BE NUMBER OF SCATTERS TO BE READ
      C        FROM INPUT FILE
      C
      C     THEN EACH SUCCEEDING LINE WILL CHARACTERIZE THE SCATTERERS AS FOLLOWS:
      C
      C
      C   SCATER(I,1)=TYPE
      C    ENTER 1 FOR FLAT PLATE
      C          2 FOR DIHEDRAL
      C          3 FOR TRIHEDRAL
```

```
C          4 FOR DIPOLE
C
C   SCATER(I,2)= SIZE (SQ METERS)
C   SCATER(I,3) = ORIENTATION ANGLE IN DEGREES
C   SCATER(I,4)=ONE WAY DISTANCE FROM LEADING EDGE OF RANGE CELL (METERS)
C
      READ (22,6002)NSCAT
      CALL PLOT(0)
      CALL V14CSZ(4)
      TYPE 6010,IFILE,ASCALE,NSCAT
      DO 50 I=1,NSCAT
      READ (22,6011)(SCATER(I,K),K=1,4)
 50   TYPE 6009,(SCATER(I,K),K=1,4)
      CALL V14CSZ(1)
      CALL CLOSE(22)
      DO 60 I=1,NSCAT
 60   SCATER(I,3)=SCATER(I,3)*CDR
      IFSTFQ=1     !START FREQ @ STEP 1 OF UP RAMP
      ASNRH=0.     !INITIATE ACCUMULATOR FOR NOISE-FREE H CHANNEL SIGNAL
      ASNRV=0.
      DO 200 IF=1,NSTEP
      F=FREQ(IF)
      LAMDA=C/F
      PHIF=PI4/LAMDA
      EHACC=CMPLX(0.,0.)  !INITAITE H ACCUMULATOR
      EVACC=CMPLX(0.,0.)  !INITIATE V ACCUMULATOR
      DO 100 I=1,NSCAT
      PHIFD=PHIF*SCATER(I,4)
      CALL GETSM(I)
      ANGH=CMPLX(0.,PHIRH+PHIFD)  !EFFECTIVE HOR PHASE SHIFT
      ANGV=CMPLX(0.,PHIRV+PHIFD)  !EFFECTIVE VERT PHASE SHIFT
      ETHOR=EHT*CEXP(-ANGH)
      ETVERT=EVT*CEXP(-ANGV)
      SCALE=RSCALE(LAMDA)
      EH=SCALE*(SMATRX(1,1)*ETHOR+SMATRX(1,2)*ETVERT)
      EV=SCALE*(SMATRX(2,1)*ETHOR+SMATRX(2,2)*ETVERT)
      EHTP=EH      !SAVE PURE RECEIVE HOR SIGNAL
      EH=EH*R1+EV*R2
      EV=EV*R1+EHTP*R2    !USE PURE HOR SIG
      EHACC=EHACC+EH
 100  EVACC=EVACC+EV
      IF(NOISE.EQ.0)GOTO 120
      VN1=VNOISE(SD)
      CALL RANPH(PN1)
      VN2=VNOISE(SD)
      CALL RANPH(PN2)
      VNHI=VN1*COS(PN1)
      VNHQ=VN1*SIN(PN1)
      VNVI=VN2*COS(PN2)
      VNVQ=VN2*SIN(PN2)
      VNH=CMPLX(VNHI,VNHQ)
      VNV=CMPLX(VNVI,VNVQ)
      ASNRH=ASNRH+CABS(EHACC)          !ACCUMULATE H NOISE-FREE SIGNAL
      ASNRV=ASNRV+CABS(EVACC)          !ACCUMULATE V NOISE-FREE SIGNAL
```

```
0124          EHACC=EHACC+VNH              !ADD NOISE TO H SIGNAL
0125          EVACC=EVACC+VNV              !ADD NOISE TO V SIGNAL
0126    120   CONTINUE
0127          HI=REAL(EHACC)
0128          HQ=AIMAG(EHACC)
0129          VI=REAL(EVACC)
0130          VQ=AIMAG(EVACC)
0131          HZANG=0.
0132          VTANG=0.
0133          IF(HI.EQ.0.0.AND.HQ.EQ.0.0)GOTO 130
0135          HZANG=ATAN2(HQ,HI)
0136    130   IF(VI.EQ.0.0.AND.VQ.EQ.0.0)GOTO 140
0138          VTANG=ATAN2(VQ,VI)
0139    140   BETA=VTANG-HZANG
        C
        C  BY DEFINITION: BETA IS ZERO(0) IF EITHER HORIZONTAL
        C     OR VERTICAL ANGLE IS ZERO.
        C
0140          IF(HZANG.EQ.0.0.OR.VTANG.EQ.0.0)BETA=0.
0142          BETA=AMOD(BETA,PI2)
0143          IF(BETA.GT.PI)BETA=BETA-PI2
0145          IF(BETA.LT.-PI)BETA=PI2+BETA
0147          SBETAH(IF)=HZANG
0148          SBETAV(IF)=VTANG
0149          SFREQ(IF)=F
0150          HQSAV(IF)=HQ
0151          HISAV(IF)=HI
0152          VQSAV(IF)=VQ
0153          VISAV(IF)=VI
0154          AHSAV(IF)=CABS(EHACC)        !CALCULATING PEAK HORIZ AMPLITUDE
0155          AVSAV(IF)=CABS(EVACC)        !CALCULATING PEAK VERT AMPLITUDE
0156          BETSAV(IF)=BETA
0157          RHCSAV(IF)=V1DSR2*CMPLX((HI+VQ),(HQ-VI))
0158          LHCSAV(IF)=V1DSR2*CMPLX((HI-VQ),(HQ+VI))
0159          LBETA=ATAN2((HQ+VI),(HI-VQ))
0160          RBETA=ATAN2((HQ-VI),(HI+VQ))
0161          CBETA=LBETA-RBETA
0162          CBETA=AMOD(CBETA,PI2)
0163          IF(CBETA.GT.PI)CBETA=CBETA-PI
0165          IF(CBETA.LT.-PI)CBETA=CBETA+PI
0167          CBETAS(IF)=CBETA
0168    200   CONTINUE
0169          N=ALOG10(FLOAT(NFFT))/ALOG10(2.)+0.5
0170          IF(IRUN.EQ.1)CALL ANORM(N,NFFT,NSTEP,BIG)
0172          SNRH=99.99  !VALUE IF NOISE IS TURNED OFF
0173          SNRV=99.99
0174          IF(NOISE.EQ.0)GOTO 210
        C
        C  CALCULATE AVERAGE RMS NOISE-FREE SINGLE PULSE SNR FOR EACH CHANNEL
        C
0176          SNRH=20.*ALOG10(V1DSR2*ASNRH/(FLOAT(NSTEP)*SD))
0177          SNRV=20.*ALOG10(V1DSR2*ASNRV/(FLOAT(NSTEP)*SD))
        C
0178    210   CALL SNR(ISN)
```

```
              IF(IAND(ISW,2).EQ.2)ICPY=1
              IF(IAND(ISW,1).EQ.0)GOTO 250
              CALL ASSIGN (6,'LP: ',0)
              WRITE (6,6008)
              DO 220 I=1,NSTEP
        220   WRITE (6,6007)SFREQ(I),HISAV(I),HQSAV(I),VISAV(I),VQSAV(I),
             1   AHSAV(I),AVSAV(I),BETSAV(I),SBETAH(I),SBETAV(I)
              CALL CLOSE (6)
        250   CALL ASSIGN(22,'DK:PTSSIM.NAM ',0,'RDO')
              ICIR=0
        300   CALL PLOT(0)
              IFIRST=1
              XMIN=(CF-FBW/2.)/1.E9
              XMAX=(CF+FBW/2.)/1.E9
              YMIN=0.
              YMAX=ASCALE
              CALL AXES(A,XMIN,XMAX,(XMAX-XMIN)/50.,YMIN,YMAX,
             1   (YMAX-YMIN)/50.,XMIN,YMIN,840.,600.,150.,100.)
              READ(22,6006)NXAXIS
              READ(22,6006)NYAXIS
              CALL LABEL(A,NXAXIS,NYAXIS)
              CALL HEADER
        C
        C  PLOTTING HORIZ OR RHC AMPLITUDE
        C
              DO 400 IF=1,NSTEP
              X=SFREQ(IF)/1.E9
              IF(ICIR.EQ.0)Y=AHSAV(IF)      !GETTING PEAK HORIZ AMPLITUDE
              IF(ICIR.EQ.1)Y=CABS(RHCSAV(IF))      !GETTING PEAK RHC AMPLITUDE
              IF(IFIRST.EQ.1)CALL LINE(A,X,Y/UVOLTS,0)
              IFIRST=0
        400   CALL LINE(A,X,Y/UVOLTS,1)
              IF(ICPY.EQ.0) GOTO 410
              CALL HRDCPY
              CALL STALL
              GOTO 420
        410   ACCEPT 6006,IANS
        420   CALL PLOT(0)
              IFIRST=1
              XMIN=(CF-FBW/2.)/1.E9
              XMAX=(CF+FBW/2.)/1.E9
              YMIN=0.
              YMAX=ASCALE
              CALL AXES(A,XMIN,XMAX,(XMAX-XMIN)/50.,YMIN,YMAX,
             1   (YMAX-YMIN)/50.,XMIN,YMIN,840.,600.,150.,100.)
              READ(22,6006)NXAXIS
              READ(22,6006)NYAXIS
              CALL LABEL(A,NXAXIS,NYAXIS)
              CALL HEADER
        C
        C  PLOTTING VERT OR LHC AMPLITUDE
        C
              DO 500 IF=1,NSTEP
              X=SFREQ(IF)/1.E9
```

```
          IF(ICIR.EQ.0)Y=AVSAV(IF)     !GETTING PEAK VERT AMPLITUDE
          IF(ICIR.EQ.1)Y=CABS(LHCSAV(IF))      !LOADING PEAK LHC AMPLITUDE
          IF(IFIRST.EQ.1)CALL LINE(A,X,Y/UVOLTS,0)
          IFIRST=0
    500   CALL LINE(A,X,Y/UVOLTS,1)
          IF(ICPY.EQ.0) GOTO 510
          CALL HRDCPY
          CALL STALL
          GOTO 520
    510   ACCEPT 6006,IANS
    520   IFIRST=1
          XMIN=(CF-FBW/2.)/1.E9
          XMAX=(CF+FBW/2.)/1.E9
          YMIN=-180.
          YMAX=180.
          CALL PLOT(0)
          CALL AXES(A,XMIN,XMAX,(XMAX-XMIN)/50.,YMIN,YMAX,
         1    (YMAX-YMIN)/50.,XMIN,YMIN,840.,600.,150.,100.)
          READ(22,6006)NXAXIS
          READ(22,6006)NYAXIS
          CALL LABEL(A,NXAXIS,NYAXIS)
          CALL HEADER
C
C   PLOTTING PHASE BETWEEN H & V OR RHC & LHC
C
          DO 600 IF=1,NSTEP
          X=SFREQ(IF)/1.E9
          IF(ICIR.EQ.0)Y=BETSAV(IF)*180./PI
          IF(ICIR.EQ.1)Y=CBETAS(IF)*180./PI
          IF(IFIRST.EQ.1)CALL LINE(A,X,Y,0)
          IFIRST=0
    600   CALL LINE(A,X,Y,1)
          IF(ICPY.EQ.0) GOTO 610
          CALL HRDCPY
          CALL STALL
          GOTO 620
    610   ACCEPT 6006,IANS
    620   CONTINUE
          DO 1500 IFFT=1,2
          DO 1010 I=1,NFFT
   1010   VALUE(I)=CMPLX(0.,0.)          !ZERO OUT COMPLEX BUFFER VALUE
          DO 1020 I=1,NSTEP
          IF(ICIR.EQ.0.AND.IFFT.EQ.1)VALUE(I)=
         1      CMPLX(HISAV(I),HQSAV(I))          !LOAD BUFFER WITH HORIZ I&Q
          IF(ICIR.EQ.0.AND.IFFT.EQ.2)VALUE(I)=
         1    CMPLX(AHSAV(I),0.)          !LOAD BUFFER REAL PART WITH HORIZ AMP
          IF(ICIR.EQ.1.AND.IFFT.EQ.1)VALUE(I)=RHCSAV(I)         !LOAD BUFFER WITH RH
          IF(ICIR.EQ.1.AND.IFFT.EQ.2)VALUE(I)=
         1    CMPLX(CABS(RHCSAV(I)),0.)           !LOAD BUFFER REAL PART WITH RHC PEAK
   1020   CONTINUE
          AVGVAL=CMPLX(0.,0.)
          GOTO 1070
C
C   REMOVE DC VALUE FROM FFT INPUT (IF IMPLEMENTED)
```

```
C
C       DO 1050 I=1,NSTEP
C1050   AVGVAL=AVGVAL+VALUE(I)
C       AVGVAL=AVGVAL/FLOAT(NSTEP)
C       DO 1060 I=1,NSTEP
C1060   VALUE(I)=VALUE(I)-AVGVAL
 1070   CONTINUE
C       CALL BHWATE(VALUE,N)          !FFT INPUT WEIGHTING IF CALLED
        CALL NLOGN(N,VALUE,+1.)
        CALL PLOT (0)
        DELX=C/(2.*FBW)
        IXMAX=IFIX(DELX*(NFFT-1)+0.5)
        IREMAN=MOD(IXMAX,5)
        IF(IREMAN.EQ.0)GOTO 1080
        IXMAX=IXMAX+(5-IREMAN)
 1080   XMIN=0.
        XMAX=FLOAT(IXMAX)
        YMIN=0.
        YMAX=1.
        CALL AXES (A,XMIN,XMAX,(XMAX-XMIN)/50.,
     1    YMIN,YMAX,(YMAX-YMIN)/50.,XMIN,YMIN,840.,600.,150.,100.)
        READ (22,6006)NXAXIS
        READ (22,6006)NYAXIS
        CALL LABEL(A,NXAXIS,NYAXIS)
        CALL HEADER
C
C  PLOTTING FFT OF HORIZ OR RHC CHANNEL
C
        DO 1100 I=1,NFFT
        X=(I-1)*DELX
        Y=CABS(VALUE(I))/BIG
        CALL LINE(A,X,0.,0)
 1100   CALL LINE(A,X,Y,1)
        IF(ICPY.EQ.0) GOTO 1110
        CALL HRDCPY
        CALL STALL
        GOTO 1120
 1110   ACCEPT 6006,IANS
 1120   CALL PLOT (0)
        XMIN=0.
        XMAX=FLOAT(IXMAX)
        YMIN=-180.
        YMAX=180.
        CALL AXES (A,XMIN,XMAX,(XMAX-XMIN)/50.,
     1    YMIN,YMAX,(YMAX-YMIN)/50.,XMIN,YMIN,840.,600.,150.,100.)
        READ (22,6006)NXAXIS
        READ (22,6006)NYAXIS
        CALL LABEL(A,NXAXIS,NYAXIS)
        CALL HEADER
C
C  PLOTTING HORIZ OR RHC FFT PHASE ANGLE DATA
C
        DO 1200 I=1,NFFT
        X=(I-1)*DELX
```

```
           Y=ATAN2(AIMAG(VALUE(I)),REAL(VALUE(I)))
           Y=AMOD(Y,PI2)
           IF(Y.GT.PI)Y=Y-PI2
           IF(Y.LT.-PI)Y=PI2+Y
           Y=Y*180./PI
           CALL LINE(A,X,0.,0)
     1200  CALL LINE(A,X,Y,1)
           IF(ICPY.EQ.0) GOTO 1210
           CALL HRDCPY
           CALL STALL
           GOTO 1500
     1210  ACCEPT 6006,IANS
     1500  CONTINUE
           DO 2500 IFFT=1,2
           DO 2010 I=1,NFFT
     2010  VALUE(I)=CMPLX(0.,0.)        !ZERO OUT COMPLEX BUFFER VALUE
           DO 2020 I=1,NSTEP
           IF(ICIR.EQ.0.AND.IFFT.EQ.1)VALUE(I)=
          1   CMPLX(VISAV(I),VQSAV(I)) !LOAD BUFFER WITH VERT I&Q
           IF(ICIR.EQ.0.AND.IFFT.EQ.2)VALUE(I)=
          1   CMPLX(AVSAV(I),0.)        !LOAD BUFFER REAL PART WITH VERT AMP
           IF(ICIR.EQ.1.AND.IFFT.EQ.1)VALUE(I)=LHCSAV(I)       !LOAD BUFFER WITH LH
           IF(ICIR.EQ.1.AND.IFFT.EQ.2)VALUE(I)=
          1   CMPLX(CABS(LHCSAV(I)),0.)        !LOAD BUFFER REAL PART WITH LHC AMP
     2020  CONTINUE
           AVGVAL=CMPLX(0.,0.)
           GOTO 2070
      C
      C   REMOVE DC VALUE FROM FFT INPUT (IF IMPLEMENTED)
      C
      C    DO 2050 I=1,NSTEP
      C2050 AVGVAL=AVGVAL+VALUE(I)
      C    AVGVAL=AVGVAL/FLOAT(NSTEP)
      C    DO 2060 I=1,NSTEP
      C2060 VALUE(I)=VALUE(I)-AVGVAL
     2070  CONTINUE
      C    CALL DHWATE(VALUE,N)        !FFT INPUT WEIGHTING IF CALLED
           CALL NLOGN(N,VALUE,+1.)
           CALL PLOT (0)
           XMIN=0.
           XMAX=FLOAT(IXMAX)
           YMIN=0.
           YMAX=1.
           CALL AXES (A,XMIN,XMAX,(XMAX-XMIN)/50.,
          1   YMIN,YMAX,(YMAX-YMIN)/50.,XMIN,YMIN,840.,600.,150.,100.)
           READ (22,6006)NXAXIS
           READ (22,6006)NYAXIS
           CALL LABEL(A,NXAXIS,NYAXIS)
           CALL HEADER
      C
      C  PLOTTING FFT OF VERT OR LHC CHNL
      C
           DO 2100 I=1,NFFT
           X=(I-1)*DELX
```

```
            Y=CABS(VALUE(I))/BIG
            CALL LINE(A,X,0.,0)
      2100  CALL LINE(A,X,Y,1)
            IF(ICPY.EQ.0) GOTO 2110
            CALL HRDCPY
            CALL STALL
            GOTO 2120
      2110  ACCEPT 6006,IANS
      2120  CALL PLOT (0)
            XMIN=0.
            XMAX=FLOAT(IXMAX)
            YMIN=-180.
            YMAX=180
            CALL AXES (A,XMIN,XMAX,(XMAX-XMIN)/50.,
           1   YMIN,YMAX,(YMAX-YMIN)/50.,XMIN,YMIN,840.,600.,150.,100.)
            READ (22,6006)NXAXIS
            READ (22,6006)NYAXIS
            CALL LABEL(A,NXAXIS,NYAXIS)
            CALL HEADER
      C
      C  PLOTTING VERT OR LHC FFT PHASE ANGLE
      C
            DO 2200 I=1,NFFT
            X=(I-1)*DELX
            Y=ATAN2(AIMAG(VALUE(I)),REAL(VALUE(I)))
            Y=AMOD(Y,PI2)
            IF(Y.GT.PI)Y=Y-PI2
            IF(Y.LT.-PI)Y=PI2+Y
            Y=Y*180./PI
            CALL LINE(A,X,0.,0)
      2200  CALL LINE(A,X,Y,1)
            IF(ICPY.EQ.0) GOTO 2210
            CALL HRDCPY
            CALL STALL
            GOTO 2500
      2210  ACCEPT 6006,IANS
      2500  CONTINUE
            IF(ICIR.EQ.1)GOTO 2600
            ICIR=1
            GOTO 300
      2600  CALL CLOSE (22)
            IRUN=IRUN+1
            IF(IRUN.EQ.4)GOTO 3000
            GOTO 11111
      3000  CALL V14CSZ(4)
      C
      C
      6012  FORMAT(8A2)
      6011  FORMAT(4F20.0)
      6010  FORMAT(1X,'FILE NAME: '8A2/
           1   1X,'SCALE: ',F7.0/1X,'NUMBER SCATTERS: ',I6/)
      6009  FORMAT(1X,3(F7.2,','),F7.2)
      6008  FORMAT(1X,T5,'FREQ',
           1   T18,'HORZ I',T31,'HORZ Q',T44,'VERT I',T57,'VERT Q',
```

```
             1   T70,'HORZ AMP',T83,'VERT AMP',T96,'BETA',
             1   T109,'H BETA',T122,'V BETA')
0425   6007  FORMAT(10(2X,1PE11.4))
0426   6006  FORMAT(20A2)
0427   6005  FORMAT(' ANTENNA ISOLATION IN DB')
0428   6004  FORMAT(F10.0)
0429   6003  FORMAT(' NUMBER OF FREQUENCY RAMP STEPS?'/)
0430   6002  FORMAT(I6)
0431   6001  FORMAT(/' NUMBER OF FFT POINTS (LESS OR EQUAL 256'/)
0432   6000  FORMAT(' RUN NUMBER ',I3//' DATA FILE FOR SCATTERERS'/)
0433         END
```

```
FORTRAN IV      STORAGE MAP

NAME      OFFSET   ATTRIBUTES

NXAXIS    000006   INTEGER*2 ARRAY (20)
NYAXIS    000056   INTEGER*2 ARRAY (20)
A         000126   REAL*4    ARRAY (20)
LBETA     001200   REAL*4    VARIABLE
LAMDA     001204   REAL*4    VARIABLE
AVGVAL    001210   COMPLEX*8 VARIABLE
EH        001220   COMPLEX*8 VARIABLE
EV        001230   COMPLEX*8 VARIABLE
ETHOR     001240   COMPLEX*8 VARIABLE
ETVERT    001250   COMPLEX*8 VARIABLE
ANGH      001260   COMPLEX*8 VARIABLE
ANGV      001270   COMPLEX*8 VARIABLE
EHTP      001300   COMPLEX*8 VARIABLE
EVTP      001310   COMPLEX*8 VARIABLE
EHT       001320   COMPLEX*8 VARIABLE
EVT       001330   COMPLEX*8 VARIABLE
ANGHT     001340   COMPLEX*8 VARIABLE
ANGVT     001350   COMPLEX*8 VARIABLE
EHACC     001360   COMPLEX*8 VARIABLE
EVACC     001370   COMPLEX*8 VARIABLE
VNH       001400   COMPLEX*8 VARIABLE
VNV       001410   COMPLEX*8 VARIABLE
V10SR2    001420   REAL*4    VARIABLE
SQRT      000000   REAL*4    PROCEDURE
UVOLTS    001424   REAL*4    VARIABLE
C         001430   REAL*4    VARIABLE
ICPY      001434   INTEGER*2 VARIABLE
IRUN      001436   INTEGER*2 VARIABLE
PI        001440   REAL*4    VARIABLE
PI2       001444   REAL*4    VARIABLE
PI4       001450   REAL*4    VARIABLE
CDR       001454   REAL*4    VARIABLE
PLOT      000000   REAL*4    PROCEDURE
V14CSZ    000000   REAL*4    PROCEDURE
XMIT      000000   REAL*4    PROCEDURE
E1H       001460   REAL*4    VARIABLE
E1V       001464   REAL*4    VARIABLE
PHITV     001470   REAL*4    VARIABLE
R1        001474   REAL*4    VARIABLE
R2        001500   REAL*4    VARIABLE
CMPLX     000000   COMPLEX*8 PROCEDURE
CEXP      000000   COMPLEX*8 PROCEDURE
PHIRH     001504   REAL*4    VARIABLE
PHIRV     001510   REAL*4    VARIABLE
NFFT      001514   INTEGER*2 VARIABLE
ASSIGN    000000   REAL*4    PROCEDURE
RIFBW     001516   REAL*4    VARIABLE
RNFDB     001522   REAL*4    VARIABLE
RNF       001526   REAL*4    VARIABLE
VARI      001532   REAL*4    VARIABLE
PRF       001536   REAL*4    VARIABLE
FLOAT     000000   REAL*4    PROCEDURE
```

```
FORTRAN IV      STORAGE MAP

NAME     OFFSET   ATTRIBUTES

ANTG     001542   REAL*4     VARIABLE
ASCALE   001546   REAL*4     VARIABLE
I        001552   INTEGER*2  VARIABLE
K        001554   INTEGER*2  VARIABLE
CLOSE    000000   REAL*4     PROCEDURE
ASNRH    001556   REAL*4     VARIABLE
ASNRV    001562   REAL*4     VARIABLE
IF       001566   INTEGER*2  VARIABLE
F        001570   REAL*4     VARIABLE
FREQ     000000   REAL*4     PROCEDURE
PHIF     001574   REAL*4     VARIABLE
PHIFD    001600   REAL*4     VARIABLE
GETSM    000000   REAL*4     PROCEDURE
SCALE    001604   REAL*4     VARIABLE
RSCALE   000000   REAL*4     PROCEDURE
VN1      001610   REAL*4     VARIABLE
VNOISE   000000   REAL*4     PROCEDURE
RANPH    000000   REAL*4     PROCEDURE
PN1      001614   REAL*4     VARIABLE
VN2      001620   REAL*4     VARIABLE
PN2      001624   REAL*4     VARIABLE
VNHI     001630   REAL*4     VARIABLE
COS      000000   REAL*4     PROCEDURE
VNHQ     001634   REAL*4     VARIABLE
SIN      000000   REAL*4     PROCEDURE
VNVI     001640   REAL*4     VARIABLE
VNVQ     001644   REAL*4     VARIABLE
CABS     000000   REAL*4     PROCEDURE
HI       001650   REAL*4     VARIABLE
REAL     000000   REAL*4     PROCEDURE
HQ       001654   REAL*4     VARIABLE
AIMAG    000000   REAL*4     PROCEDURE
VI       001660   REAL*4     VARIABLE
VQ       001664   REAL*4     VARIABLE
HZANG    001670   REAL*4     VARIABLE
VTANG    001674   REAL*4     VARIABLE
ATAN2    000000   REAL*4     PROCEDURE
BETA     001700   REAL*4     VARIABLE
AMOD     000000   REAL*4     PROCEDURE
RBETA    001704   REAL*4     VARIABLE
CBETA    001710   REAL*4     VARIABLE
N        001714   INTEGER*2  VARIABLE
ALOG10   000000   REAL*4     PROCEDURE
ANORM    000000   REAL*4     PROCEDURE
SWR      000000   REAL*4     PROCEDURE
ISW      001716   INTEGER*2  VARIABLE
IAND     000000   INTEGER*2  PROCEDURE
ICIR     001720   INTEGER*2  VARIABLE
IFIRST   001722   INTEGER*2  VARIABLE
XMIN     001724   REAL*4     VARIABLE
XMAX     001730   REAL*4     VARIABLE
YMIN     001734   REAL*4     VARIABLE
```

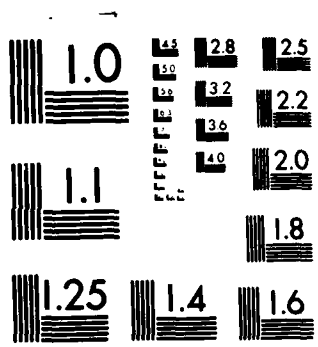
```
FORTRAN IV      STORAGE MAP

NAME     OFFSET  ATTRIBUTES

YMAX     001740  REAL*4     VARIABLE
AXES     000000  REAL*4     PROCEDURE
LABEL    000000  INTEGER*2 PROCEDURE
HEADER   000000  REAL*4     PROCEDURE
X        001744  REAL*4     VARIABLE
Y        001750  REAL*4     VARIABLE
LINE     000000  INTEGER*2 PROCEDURE
HRDCPY   000000  REAL*4     PROCEDURE
STALL    000000  REAL*4     PROCEDURE
IANS     001754  INTEGER*2 VARIABLE
IFFT     001756  INTEGER*2 VARIABLE
NLOGN    000000  INTEGER*2 PROCEDURE
DELX     001760  REAL*4     VARIABLE
IXMAX    001764  INTEGER*2 VARIABLE
IFIX     000000  INTEGER*2 PROCEDURE
IREMAN   001766  INTEGER*2 VARIABLE
MOD      000000  INTEGER*2 PROCEDURE


COMMON BLOCK /WORKF/    LENGTH 000024

IFSTFQ   000000  INTEGER*2 VARIABLE
IUP      000002  INTEGER*2 VARIABLE
LSTEP    000004  INTEGER*2 VARIABLE
NSTEP    000006  INTEGER*2 VARIABLE
DF       000010  REAL*4     VARIABLE
CF       000014  REAL*4     VARIABLE
FDW      000020  REAL*4     VARIABLE

COMMON BLOCK /WKSCT/    LENGTH 003140

SCATER   000000  REAL*4     ARRAY (100,4) VECTORED
SMATRX   003100  COMPLEX*8 ARRAY (2,2) VECTORED

COMMON BLOCK /HEAD/     LENGTH 000114

AISOL    000000  REAL*4     VARIABLE
NSCAT    000004  INTEGER*2 VARIABLE
GAINA    000006  REAL*4     VARIABLE
NOISE    000012  INTEGER*2 VARIABLE
RANGE    000014  REAL*4     VARIABLE
OBLOSS   000020  REAL*4     VARIABLE
VXMIT    000024  INTEGER*2 ARRAY (2)
IFILE    000030  INTEGER*2 ARRAY (8)
SO       000050  REAL*4     VARIABLE
SIG      000054  REAL*4     VARIABLE
SNRH     000060  REAL*4     VARIABLE
SNRV     000064  REAL*4     VARIABLE
SNRHI    000070  REAL*4     VARIABLE
SNRHQ    000074  REAL*4     VARIABLE
SNRVI    000100  REAL*4     VARIABLE
SNRVQ    000104  REAL*4     VARIABLE
```

```
FORTRAN IV      STORAGE MAP

NAME     OFFSET  ATTRIBUTES

SNR      000110  REAL*4     VARIABLE

COMMON BLOCK /WORK/      LENGTH 042000

HQSAV    000000  REAL*4     ARRAY (256)
HISAV    002000  REAL*4     ARRAY (256)
VQSAV    004000  REAL*4     ARRAY (256)
VISAV    006000  REAL*4     ARRAY (256)
SFREQ    010000  REAL*4     ARRAY (256)
SBETAH   012000  REAL*4     ARRAY (256)
SBETAV   014000  REAL*4     ARRAY (256)
BETSAV   016000  REAL*4     ARRAY (256)
RHCSAV   020000  COMPLEX*8  ARRAY (256)
LHCSAV   024000  COMPLEX*8  ARRAY (256)
CBETAS   030000  REAL*4     ARRAY (256)
AHSAV    032000  REAL*4     ARRAY (256)
AVSAV    034000  REAL*4     ARRAY (256)
VALUE    036000  COMPLEX*8  ARRAY (256)

COMMON BLOCK /SIGNAL/    LENGTH 000030

PTPWR    000000  REAL*4     VARIABLE
RANGE4   000004  REAL*4     VARIABLE
CR       000010  REAL*4     VARIABLE
ANTG2    000014  REAL*4     VARIABLE
SLOSS    000020  REAL*4     VARIABLE
PI4C     000024  REAL*4     VARIABLE
```

```
      SUBROUTINE XMIT (E1H,E1V,PHITV,NAME)
C
C  THIS SUBROUTINE DETERMINES THE TRANSMITTED SIGNAL POLARIZATION
C
      INTEGER NAME (2)
      INTEGER RHC(2),LHC(2),HOR(2),VER(2),HV(2)
      DATA RHC,LHC,HOR,VER,HV/'RH','C ','LH','C ','HO','R ',
     1   'VE','R ','H-','V '/
      PI=3.14159
1     CALL PLOT(0)
      TYPE 10
10    FORMAT(' 1 - RHC'/' 2 - LHC'/' 3 - HORIZONTAL'/' 4 - VERTICAL'/
     1  ' 5 - HORIZONTAL & VERTICAL'/)
      ACCEPT 15,IXMIT
15    FORMAT(I6)
      IF(IXMIT.LT.1.OR.IXMIT.GT.5)GOTO 1
      GOTO (100,200,300,400,500)IXMIT
100   E1H=1.
      E1V=1.
      PHITV=-PI/2
      NAME(1)=RHC(1)
      NAME(2)=RHC(2)
      RETURN
200   E1H=1.
      E1V=1.
      PHITV=+PI/2
      NAME(1)=LHC(1)
      NAME(2)=LHC(2)
      RETURN
300   E1H=1.
      E1V=0.
      PHITV=0.
      NAME(1)=HOR(1)
      NAME(2)=HOR(2)
      RETURN
400   E1H=0.
      E1V=1.
      PHITV=0.
      NAME(1)=VER(1)
      NAME(2)=VER(2)
      RETURN
500   E1H=1.
      E1V=1.
      PHITV=0.
      NAME(1)=HV(1)
      NAME(2)=HV(2)
      RETURN
      END
```

```
FORTRAN IV      STORAGE MAP

NAME     OFFSET  ATTRIBUTES

NAME     000022  INTEGER*2 PARAMETER ARRAY (2)
RHC      000024  INTEGER*2 ARRAY (2)
LHC      000030  INTEGER*2 ARRAY (2)
HOR      000034  INTEGER*2 ARRAY (2)
VER      000040  INTEGER*2 ARRAY (2)
HV       000044  INTEGER*2 ARRAY (2)
E1H      000014  REAL*4    PARAMETER VARIABLE
E1V      000016  REAL*4    PARAMETER VARIABLE
PHITV    000020  REAL*4    PARAMETER VARIABLE
PI       000214  REAL*4    VARIABLE
PLOT     000000  REAL*4    PROCEDURE
IXMIT    000220  INTEGER*2 VARIABLE
```

```
FORTRAN IV      V01C-03F+  THU 28-OCT-82 00:06:57                PAGE 001

0001          SUBROUTINE BHWATE(A,N)
        C
        C   FFT INPUT WEIGHTING
        C
0002          COMPLEX A(N)
0003          DATA PI2/6.283185/
0004          DO 100 I=1,N
0005          WATE=0.42323-0.49755*COS(PI2/N*(I-1))+0.07922*COS(PI2/N*2*(I-1))
0006    100   A(I)=A(I)*WATE
0007          RETURN
0008          END


FORTRAN IV      STORAGE MAP

NAME     OFFSET  ATTRIBUTES

A        000014  COMPLEX*8 PARAMETER ARRAY (N)
N        000016  INTEGER*2 PARAMETER VARIABLE
PI2      000020  REAL*4    VARIABLE
I        000040  INTEGER*2 VARIABLE
WATE     000042  REAL*4    VARIABLE
COS      000000  REAL*4    PROCEDURE


FORTRAN IV      V01C-03F+  THU 28-OCT-82 00:07:02                PAGE 001

0001          FUNCTION VNOISE(SD)
        C
        C   THIS FUNCTION GENERATES GAUSSIAN DISTRIBUTED NOISE VOLTAGE
        C
0002          SUM=0.
0003          DO 10 I=1,12
0004    10    SUM=SUM+RANF(U)
0005          VNOISE=(SUM-6.)*SD
0006          RETURN
0007          END


FORTRAN IV      STORAGE MAP

NAME     OFFSET  ATTRIBUTES

VNOISE   000016  REAL*4    VARIABLE
SD       000014  REAL*4    PARAMETER VARIABLE
SUM      000022  REAL*4    VARIABLE
I        000026  INTEGER*2 VARIABLE
RANF     000000  REAL*4    PROCEDURE
U        000030  REAL*4    VARIABLE
```



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

```
FORTRAN IV      V01C-03F+  THU 28-OCT-82 00:07:06                 PAGE 001

           C
0001             SUBROUTINE RANPH(PHASE)
           C
           C  THIS SUBROUTINE GENERATES UNIFORMALLY DISTRIBUTED PHASE NOISE
           C
0002             DATA PI /3.14159/
0003             PHASE=(RANF(U)-.5)*PI
0004             RETURN
0005             END
```

```
FORTRAN IV      STORAGE MAP

NAME     OFFSET  ATTRIBUTES

PHASE    000014  REAL*4     PARAMETER VARIABLE
PI       000016  REAL*4     VARIABLE
RANF     000000  REAL*4     PROCEDURE
U        000022  REAL*4     VARIABLE
```

```
FORTRAN IV      V01C-03F+  THU 28-OCT-82 00:07:10                 PAGE 001

           C
0001             FUNCTION RANF(U)
           C
           C  UNIFORM NUMBER GENERATOR
           C
0002             DATA I,J/0,0/
0003             RANF=RAN(I,J)
0004             RETURN
0005             END
```

```
FORTRAN IV      STORAGE MAP

NAME     OFFSET  ATTRIBUTES

RANF     000016  REAL*4     VARIABLE
U        000014  REAL*4     PARAMETER VARIABLE
I        000022  INTEGER*2  VARIABLE
J        000024  INTEGER*2  VARIABLE
RAN      000000  REAL*4     PROCEDURE
```

```
0001          SUBROUTINE ANORM(N,NFFT,NSTEP,BIG)
       C
       C   THIS SUBROUTINE DETERMINES THE BIGGEST FFT OUTPUT FOR NORMALIZATION
       C     OF FFT PLOTS
       C
0002          COMPLEX VALUE(256),SMATRX(2,2)
0003          DIMENSION SFREQ(256)
0004          DIMENSION SBETAH(256),SBETAV(256)
0005          DIMENSION SCATER(100,4),AHSAV(256),AVSAV(256),BETSAV(256)
0006          DIMENSION HOSAV(256),HISAV(256),VOSAV(256),VISAV(256)
0007          DIMENSION CBETAS(256)
0008          COMPLEX RHCSAV(256),LHCSAV(256)
0009          COMMON /WORK/HOSAV,HISAV,VOSAV,VISAV,SFREQ,SBETAH,SBETAV,BETSAV,
             1             RHCSAV,LHCSAV,CBETAS,AHSAV,AVSAV,
             1             VALUE
0010          COMMON /WKSCT/SCATER,SMATRX
       C
0011          BIG=0.
0012          DO 3 I=1,NFFT
0013   3      VALUE(I)=CMPLX(0.,0.)
0014          DO 5 I=1,NSTEP
0015   5      VALUE(I)=CMPLX(CABS(RHCSAV(I)),0.0) !REAL PART WITH RHC AMP
0016          CALL NLOGN (N,VALUE,+1.)
0017          CALL BIGEST(NFFT,BIG)
0018          DO 13 I=1,NFFT
0019   13     VALUE(I)=CMPLX(0.,0.)
0020          DO 15 I=1,NSTEP
0021   15     VALUE(I)=CMPLX(CABS(LHCSAV(I)),0.0) !REAL PART WITH LHC AMP
0022          CALL NLOGN (N,VALUE,+1.)
0023          CALL BIGEST(NFFT,BIG)
0024          DO 18 I=1,NFFT
0025   18     VALUE(I)=CMPLX(0.,0.)
0026          DO 20 I=1,NSTEP
0027   20     VALUE(I)=CMPLX(AHSAV(I),0.) !REAL PART WITH HORIZ AMP
0028          CALL NLOGN(N,VALUE,+1.)
0029          CALL BIGEST(NFFT,BIG)
0030          DO 23 I=1,NFFT
0031   23     VALUE(I)=CMPLX(0.,0.)
0032          DO 25 I=1,NSTEP
0033   25     VALUE(I)=CMPLX(AVSAV(I),0.) !REAL PART WITH VERT AMP
0034          CALL NLOGN(N,VALUE,+1.)
0035          CALL BIGEST(NFFT,BIG)
0036          RETURN
0037          END
```

```
FORTRAN IV      STORAGE MAP

NAME     OFFSET  ATTRIBUTES

N        000014  INTEGER*2 PARAMETER VARIABLE
NFFT     000016  INTEGER*2 PARAMETER VARIABLE
NSTEP    000020  INTEGER*2 PARAMETER VARIABLE
BIG      000022  REAL*4    PARAMETER VARIABLE
I        000050  INTEGER*2 VARIABLE
CMPLX    000000  COMPLEX*8 PROCEDURE
CABS     000000  REAL*4    PROCEDURE
NLOGN    000000  INTEGER*2 PROCEDURE
BIGEST   000000  REAL*4    PROCEDURE

COMMON BLOCK /WORK/      LENGTH 042000

HOSAV    000000  REAL*4    ARRAY (256)
HISAV    002000  REAL*4    ARRAY (256)
VOSAV    004000  REAL*4    ARRAY (256)
VISAV    006000  REAL*4    ARRAY (256)
SFREQ    010000  REAL*4    ARRAY (256)
SBETAH   012000  REAL*4    ARRAY (256)
SBETAV   014000  REAL*4    ARRAY (256)
BETSAV   016000  REAL*4    ARRAY (256)
RHCSAV   020000  COMPLEX*8 ARRAY (256)
LHCSAV   024000  COMPLEX*8 ARRAY (256)
CBETAS   030000  REAL*4    ARRAY (256)
AHSAV    032000  REAL*4    ARRAY (256)
AVSAV    034000  REAL*4    ARRAY (256)
VALUE    036000  COMPLEX*8 ARRAY (256)

COMMON BLOCK /WKSCT/    LENGTH 003140

SCATER   000000  REAL*4    ARRAY (100,4) VECTORED
SMATRX   003100  COMPLEX*8 ARRAY (2,2) VECTORED
```

```
      C
      C
0001        SUBROUTINE BIGEST(N,BIG)
0002        COMPLEX VALUE(256),SMATRX(2,2)
0003        DIMENSION SFREQ(256)
0004        DIMENSION SBETAH(256),SBETAV(256)
0005        DIMENSION SCATER(100,4),AHSAV(256),AVSAV(256),BETSAV(256)
0006        DIMENSION HQSAV(256),HISAV(256),VQSAV(256),VISAV(256)
0007        DIMENSION CBETAS(256)
0008        COMPLEX RHCSAV(256),LHCSAV(256)
0009        COMMON /WORK/HQSAV,HISAV,VQSAV,VISAV,SFREQ,SBETAH,SBETAV,BETSAV,
           1            RHCSAV,LHCSAV,CBETAS,AHSAV,AVSAV,
           1            VALUE
0010        COMMON /WKSCT/SCATER,SMATRX
      C
0011        DO 10 I=1,N
0012        AVAL=CABS(VALUE(I))
0013   10   IF(AVAL.GT.BIG)BIG=AVAL
0015        RETURN
0016        END


FORTRAN IV      STORAGE MAP

NAME     OFFSET  ATTRIBUTES

N        000014  INTEGER*2 PARAMETER VARIABLE
BIG      000016  REAL*4    PARAMETER VARIABLE
I        000034  INTEGER*2 VARIABLE
AVAL     000036  REAL*4    VARIABLE
CABS     000000  REAL*4    PROCEDURE


COMMON BLOCK /WORK/      LENGTH 042000

HQSAV    000000  REAL*4    ARRAY (256)
HISAV    002000  REAL*4    ARRAY (256)
VQSAV    004000  REAL*4    ARRAY (256)
VISAV    006000  REAL*4    ARRAY (256)
SFREQ    010000  REAL*4    ARRAY (256)
SBETAH   012000  REAL*4    ARRAY (256)
SBETAV   014000  REAL*4    ARRAY (256)
BETSAV   016000  REAL*4    ARRAY (256)
RHCSAV   020000  COMPLEX*8 ARRAY (256)
LHCSAV   024000  COMPLEX*8 ARRAY (256)
CBETAS   030000  REAL*4    ARRAY (256)
AHSAV    032000  REAL*4    ARRAY (256)
AVSAV    034000  REAL*4    ARRAY (256)
VALUE    036000  COMPLEX*8 ARRAY (256)

COMMON BLOCK /WKSCT/     LENGTH 003140

SCATER   000000  REAL*4    ARRAY (100,4) VECTORED
SMATRX   003100  COMPLEX*8 ARRAY (2,2) VECTORED
```

```
FORTRAN IV      V01C-03F+  THU 28-OCT-82 00:07:33                PAGE 001

0001          FUNCTION RSCALE (LAMDA)
        C
        C   AMPLITUDE SCALE FUNCTION
        C
0002          REAL LAMDA,IMPED
0003          COMMON /SIGNAL/PTPWR,RANGE4,CR,ANTG2,SLOSS,PI4C
0004          DATA IMPED/50./
0005          PR=PTPWR*ANTG2*(LAMDA**2.)*CR/(PI4C*RANGE4*SLOSS)
        C
        C  PEAK OUTPUT VOLTAGE IS RELATED TO AVERAGE TRANSMITTER
        C    POWER OUTPUT (WHEN TRANSMITTER IS SWITCHED ON) BY SQRT(2.)
        C
0006          RSCALE=SQRT(PR*IMPED*2.)
0007          RETURN
0008          END
```

```
FORTRAN IV      STORAGE MAP

NAME     OFFSET  ATTRIBUTES

RSCALE   000016  REAL*4     VARIABLE
LAMDA    000014  REAL*4     PARAMETER VARIABLE
IMPED    000022  REAL*4     VARIABLE
PR       000026  REAL*4     VARIABLE
SQRT     000000  REAL*4     PROCEDURE

COMMON BLOCK /SIGNAL/   LENGTH 000030

PTPWR    000000  REAL*4     VARIABLE
RANGE4   000004  REAL*4     VARIABLE
CR       000010  REAL*4     VARIABLE
ANTG2    000014  REAL*4     VARIABLE
SLOSS    000020  REAL*4     VARIABLE
PI4C     000024  REAL*4     VARIABLE
```

```
FORTRAN IV      V01C-03F+  THU 28-OCT-82 00:07:38                PAGE 001

0001          FUNCTION FREQ(I)
        C
        C  GENERATE FREQUENCY OUTPUT STEP AS A FUNCTION OF
        C     THE LAST FREQUENCY RAMP STEP TRANSMITTED
        C
0002          COMMON /WORKF/IFSTFQ,IUP,LSTEP,NSTEP,DF,CF,FBW
        C
0003          IF(IFSTFQ.NE.1)GOTO 5
0005          IFSTFQ=0
0006          FREQ=CF-FBW/2.
0007          IUP=1
0008          LSTEP=1
0009          RETURN
0010    5     IF(IUP.NE.1)GOTO 100
0012          IF(LSTEP.NE.NSTEP)GOTO 10
0014          IUP=0
0015          RETURN
0016    10    LSTEP=LSTEP+1
0017          FREQ=FREQ+DF
0018          RETURN
0019    100   IF(LSTEP.NE.1)GOTO 110
0021          IUP=1
0022          RETURN
0023    110   LSTEP=LSTEP-1
0024          FREQ=FREQ-DF
0025          RETURN
0026          END


FORTRAN IV      STORAGE MAP

NAME     OFFSET  ATTRIBUTES

FREQ     000016  REAL*4    VARIABLE
I        000014  INTEGER*2 PARAMETER VARIABLE


COMMON BLOCK /WORKF/    LENGTH 000024

IFSTFQ   000000  INTEGER*2 VARIABLE
IUP      000002  INTEGER*2 VARIABLE
LSTEP    000004  INTEGER*2 VARIABLE
NSTEP    000006  INTEGER*2 VARIABLE
DF       000010  REAL*4    VARIABLE
CF       000014  REAL*4    VARIABLE
FBW      000020  REAL*4    VARIABLE
```

```
FORTRAN IV      V01C-03F+  THU 28-OCT-82 00:07:45                PAGE 001

0001          SUBROUTINE GETSM(I)
        C
        C  DETERMINE SCATTERER TYPE AND CALL IT'S MATRIX
        C
0002          COMPLEX SMATRX(2,2)
0003          DIMENSION SCATER(100,4)
0004          COMMON /WKSCT/SCATER,SMATRX
0005          GOTO(100,200,300,400)IFIX(SCATER(I,1))
0006    100   CALL PLATE(I)
0007          RETURN
0008    200   CALL DIHED(I)
0009          RETURN
0010    300   CALL TRIHED(I)
0011          RETURN
0012    400   CALL DIPOLE(I)
0013          RETURN
0014          END


FORTRAN IV      STORAGE MAP

NAME     OFFSET  ATTRIBUTES

I        000014  INTEGER*2 PARAMETER VARIABLE
IFIX     000000  INTEGER*2 PROCEDURE
PLATE    000000  REAL*4    PROCEDURE
DIHED    000000  REAL*4    PROCEDURE
TRIHED   000000  REAL*4    PROCEDURE
DIPOLE   000000  REAL*4    PROCEDURE

COMMON BLOCK /WKSCT/    LENGTH 003140

SCATER   000000  REAL*4    ARRAY (100,4) VECTORED
SMATRX   003100  COMPLEX*8 ARRAY (2,2) VECTORED
```

```
0001        SUBROUTINE PLATE(I)
      C
      C  FLAT PLATE SCATTERING MATRIX
      C
0002        DIMENSION SCATER(100,4)
0003        COMPLEX SMATRX(2,2)
0004        COMMON /WKSCT/SCATER,SMATRX
0005        SRSIGM=SQRT(SCATER(I,2))
0006        SMATRX(1,1)=CMPLX(-1.,0.)*SRSIGM
0007        SMATRX(1,2)=CMPLX(0.,0.)*SRSIGM
0008        SMATRX(2,1)=SMATRX(1,2)
0009        SMATRX(2,2)=SMATRX(1,1)
0010        RETURN
0011        END
```

```
FORTRAN IV      STORAGE MAP

NAME     OFFSET  ATTRIBUTES

I        000014  INTEGER*2 PARAMETER VARIABLE
SRSIGM   000036  REAL*4    VARIABLE
SQRT     000000  REAL*4    PROCEDURE
CMPLX    000000  COMPLEX*8 PROCEDURE

COMMON BLOCK /WKSCT/    LENGTH 003140

SCATER   000000  REAL*4    ARRAY (100,4) VECTORED
SMATRX   003100  COMPLEX*8 ARRAY (2,2) VECTORED
```

```
FORTRAN IV      V01C-03F+  THU 28-OCT-82 00:07:56                     PAGE 001

      C
0001            SUBROUTINE DIHED(I)
      C
      C   DIHEDRAL SCATTERING MATRIX
      C
0002            DIMENSION SCATER(100,4)
0003            COMPLEX SMATRX(2,2)
0004            COMMON /WKSCT/SCATER,SMATRX
0005            SRSIGM=SQRT(SCATER(I,2))
0006            SMATRX(1,1)=CMPLX(COS(2.*SCATER(I,3)),0.)*SRSIGM
0007            SMATRX(1,2)=CMPLX(SIN(2.*SCATER(I,3)),0.)*SRSIGM
0008            SMATRX(2,1)=SMATRX(1,2)
0009            SMATRX(2,2)=CMPLX(-COS(2.*SCATER(I,3)),0.)*SRSIGM
0010            RETURN
0011            END
```

```
FORTRAN IV      STORAGE MAP

NAME     OFFSET  ATTRIBUTES

I        000014  INTEGER*2 PARAMETER VARIABLE
SRSIGM   000036  REAL*4    VARIABLE
SQRT     000000  REAL*4    PROCEDURE
CMPLX    000000  COMPLEX*8 PROCEDURE
COS      000000  REAL*4    PROCEDURE
SIN      000000  REAL*4    PROCEDURE

COMMON BLOCK /WKSCT/    LENGTH 003140

SCATER   000000  REAL*4    ARRAY (100,4) VECTORED
SMATRX   003100  COMPLEX*8 ARRAY (2,2) VECTORED
```

```
      C
0001        SUBROUTINE TRIMED(I)
      C
      C   TRIHEDRAL SCATTERING MATRIX
      C
0002        DIMENSION SCATER(100,4)
0003        COMPLEX SMATRX(2,2)
0004        COMMON /WKSCT/SCATER,SMATRX
0005        SRSIGM=SQRT(SCATER(I,2))
0006        SMATRX(1,1)=CMPLX(-1.,0.)*SRSIGM
0007        SMATRX(1,2)=CMPLX(0.,0.)*SRSIGM
0008        SMATRX(2,1)=SMATRX(1,2)
0009        SMATRX(2,2)=SMATRX(1,1)
0010        RETURN
0011        END
```

```
FORTRAN IV      STORAGE MAP

NAME     OFFSET  ATTRIBUTES

I        000014  INTEGER*2 PARAMETER VARIABLE
SRSIGM   000036  REAL*4    VARIABLE
SQRT     000000  REAL*4    PROCEDURE
CMPLX    000000  COMPLEX*8 PROCEDURE

COMMON BLOCK /WKSCT/    LENGTH 003140

SCATER   000000  REAL*4    ARRAY (100,4) VECTORED
SMATRX   003100  COMPLEX*8 ARRAY (2,2) VECTORED
```

```
FORTRAN IV      V01C-03F+  THU 28-OCT-82 00:08:07              PAGE 001

          C
0001            SUBROUTINE DIPOLE(I)
          C
          C   DIPOLE SCATTERING MATRIX
          C
0002            DIMENSION SCATER(100,4)
0003            COMPLEX SMATRX(2,2)
0004            COMMON /WKSCT/SCATER,SMATRX
0005            SRSIGM=SQRT(SCATER(I,2))
0006            SMATRX(1,1)=CMPLX(-COS(2.*SCATER(I,3)),0.)*SRSIGM
0007            SMATRX(1,2)=CMPLX(-COS(SCATER(I,3))*SIN(SCATER(I,3)),0.)*
              1    SRSIGM
0008            SMATRX(2,1)=SMATRX(1,2)
0009            SMATRX(2,2)=CMPLX(-SIN(2.*SCATER(I,3)),0.)*SRSIGM
0010            RETURN
0011            END
```

```
FORTRAN IV      STORAGE MAP

NAME     OFFSET   ATTRIBUTES

I        000014   INTEGER*2 PARAMETER VARIABLE
SRSIGM   000036   REAL*4    VARIABLE
SQRT     000000   REAL*4    PROCEDURE
CMPLX    000000   COMPLEX*8 PROCEDURE
COS      000000   REAL*4    PROCEDURE
SIN      000000   REAL*4    PROCEDURE

COMMON BLOCK /WKSCT/     LENGTH 003140

SCATER   000000   REAL*4    ARRAY (100,4) VECTORED
SMATRX   003100   COMPLEX*8 ARRAY (2,2) VECTORED
```

```
          SUBROUTINE HEADER
      C
      C  PLOTTING HEADER DATA PRINTOUT
      C
          COMPLEX SMATRX(2,2)
          DIMENSION SCATER(100,4)
          INTEGER IFILE(8),NXMIT(2),NPRES,KY,KN
          COMMON /WORKF/IFSTFQ,IOP,LSTEP,NSTEP,DF,CF,FBW
          COMMON /WKSCT/ SCATER,SMATRX
          COMMON /HEAD/AISOL,NSCAT,GAINA,NOISE,
         1   RANGE,DBLOSS,NXMIT,IFILE,SD,BIG,
         1   SNRH,SNRV,SNRHI,SNRHQ,SNRVI,SNRVQ,SNR
          COMMON /SIGNAL/PTPWR,RANGE4,CR,ANTG2,SLOSS,PI4C
          DATA KY,KN/' Y',' N'/
      C
      C
          NPRES=KN
          IF(NOISE.EQ.0)GOTO 5
          NPRES=KY
      C
      5   CALL PLOT(-1,0,760)
          CALL V14CSZ(4)
          TYPE 9
          TYPE 10,IFILE,NSCAT,NSTEP,GAINA,AISOL,NXMIT,PTPWR,
         1   CR,DBLOSS,BIG
          TYPE 11,NPRES,(SD/1.E-6),SNRH,SNRV,RANGE
      9   FORMAT(1H+,40X,'RF GUIDANCE TECHNOLOGY POLARIZATION SIMULATION')
      10  FORMAT(9X,'DATA FILE NAME:',8A2,
         1   1X,'NUM. SCATTERERS:',I3,
         1   3X,'FREQ STEPS:',I3,
         1   3X,'ANT GAIN(DB):',F7.2,
         1   3X,'ANT ISOLATION(DB)',F7.2/
         1   9X,'XMIT:',2A2,
         1   3X,'XMIT PWR/CHNL(WATTS):'F6.2,
         1   3X,'COMP RATIO:',F6.2,
         1   3X,'SYSTEM LOSS(DB):',F5.2,
         1   3X,'FFT SCALER:',1PE14.6)
      11  FORMAT(9X,'NOISE:',A2,
         1   3X,'NOISE SD(UVOLTS):',F7.5,
         1   3X,'H AVG SNR(DB):',F6.2,
         1   2X,'V AVG SNR(DB):',F6.2,
         1   3X,'RANGE TO TARGET CELL(METERS):',F8.2)
          DO 20 I=1,1000
      20  CONTINUE
          CALL V14CSZ(1)
          RETURN
          END
```

```
FORTRAN IV      STORAGE MAP

NAME     OFFSET  ATTRIBUTES

NPRES    000646  INTEGER*2 VARIABLE
KY       000014  INTEGER*2 VARIABLE
KN       000016  INTEGER*2 VARIABLE
PLOT     000000  REAL*4    PROCEDURE
V14CSZ   000000  REAL*4    PROCEDURE
I        000650  INTEGER*2 VARIABLE


COMMON BLOCK /WORKF/    LENGTH 000024

IFSTFQ   000000  INTEGER*2 VARIABLE
IOP      000002  INTEGER*2 VARIABLE
LSTEP    000004  INTEGER*2 VARIABLE
NSTEP    000006  INTEGER*2 VARIABLE
DF       000010  REAL*4    VARIABLE
CF       000014  REAL*4    VARIABLE
FRW      000020  REAL*4    VARIABLE

COMMON BLOCK /WKSCT/    LENGTH 003140

SCATER   000000  REAL*4    ARRAY (100,4) VECTORED
SMATRX   003100  COMPLEX*8 ARRAY (2,2) VECTORED

COMMON BLOCK /HEAD/     LENGTH 000114

AISOL    000000  REAL*4    VARIABLE
NSCAT    000004  INTEGER*2 VARIABLE
GAINA    000006  REAL*4    VARIABLE
NOISE    000012  INTEGER*2 VARIABLE
RANGE    000014  REAL*4    VARIABLE
OHLOSS   000020  REAL*4    VARIABLE
NXMIT    000024  INTEGER*2 ARRAY (2)
IFILE    000030  INTEGER*2 ARRAY (8)
SD       000050  REAL*4    VARIABLE
BIG      000054  REAL*4    VARIABLE
SNRH     000060  REAL*4    VARIABLE
SNRV     000064  REAL*4    VARIABLE
SNRHI    000070  REAL*4    VARIABLE
SNRHQ    000074  REAL*4    VARIABLE
SNRVI    000100  REAL*4    VARIABLE
SNRVQ    000104  REAL*4    VARIABLE
SNR      000110  REAL*4    VARIABLE

COMMON BLOCK /SIGNAL/   LENGTH 000030

PTPWR    000000  REAL*4    VARIABLE
RANGE4   000004  REAL*4    VARIABLE
CR       000010  REAL*4    VARIABLE
ANTG2    000014  REAL*4    VARIABLE
SLOSS    000020  REAL*4    VARIABLE
PI4C     000024  REAL*4    VARIABLE
```

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